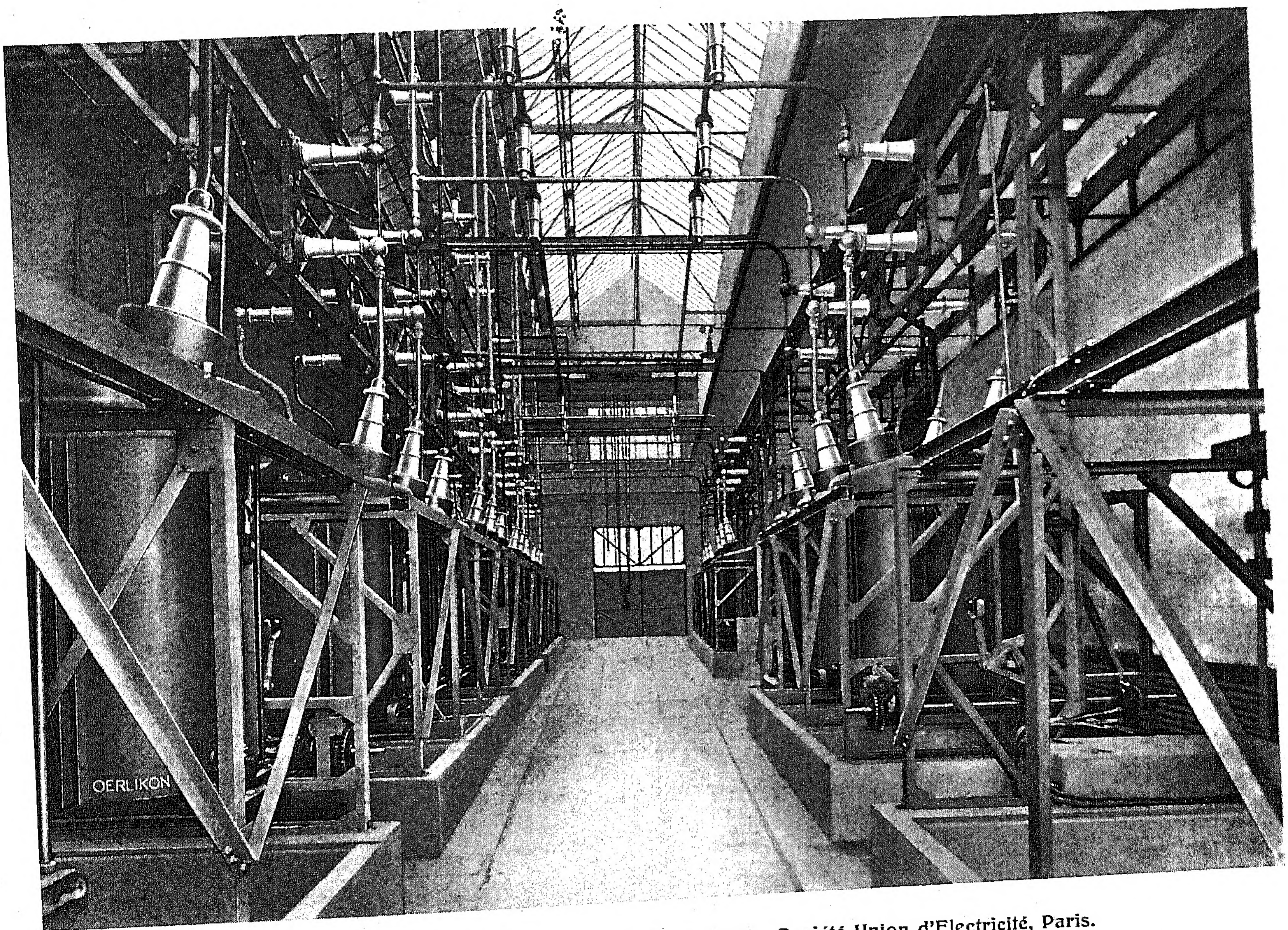
ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

BULLETIN OERLIKON

No. 55 — January 1926

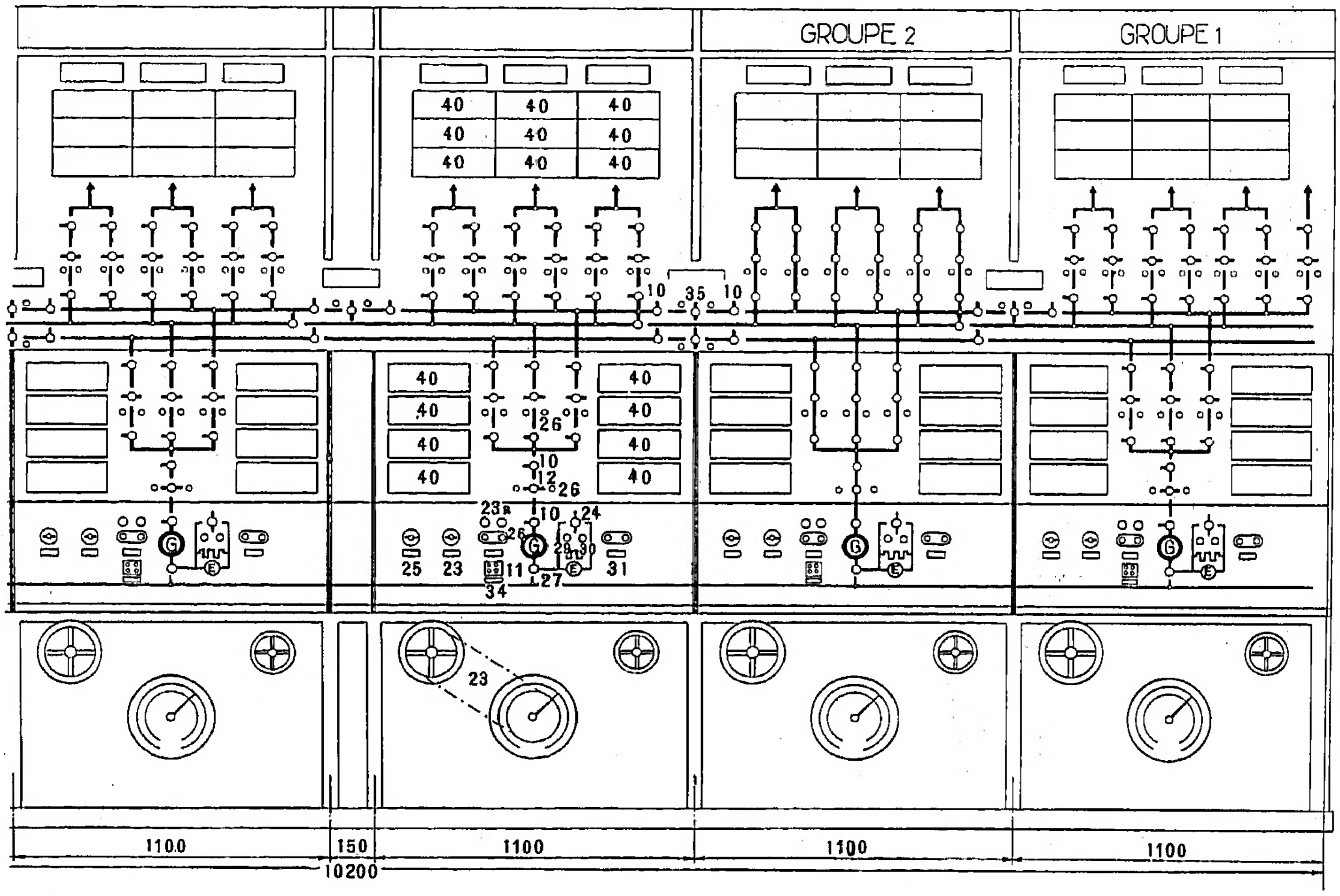


Large Oerlikon oil immersed circuit breakers for the Société Union d'Electricité, Paris.
60000 volt switch room at the Argenteuil distribution station
of the Gennevilliers power station.

On Mimic Busbar Systems.

The necessity of supplying electrical energy on an extensive scale to meet the increasing demand has led to the construction of large generating stations, and to the laying out of vast networks of distribution lines. This has entailed, on the one hand, the adoption of high pre[illegible]ures in order to keep the losses in these systems within economical limits and, on the other hand, the provision of circuit breakers for the greatest rupturing capacities, so as to be able to deal with the heavy short-circuit currents liable to occur in such installations. At the same time the number of feeder circuits and of busbars in the power stations has been considerably increased in view of the present practice of dividing the distribution network into various sections with separate feeders, in order to have the means of preventing local disturbances from affecting the whole system. Such conditions have necessitated the construction of switch houses so extensive in size as to render the direct control of the installation very difficult. In order to remedy this, the switchgear to be operated

during normal service is now controlled from a separate control room where the measuring instruments are also mounted. The switchboard or switch desk provided in this control room permits of the regulation of the pressure of generator and of the speed of turbine; it also indicates which machines and feeders are in circuit and gives the busbar pressure and frequency. Furthermore, provision is made for signalling devices which come into play when the circuit breakers are tripped automatically. The duties of the switchboard attendant are thus greatly simplified, insofar as normal operation is concerned.



(1) Generator 6000 volts. (2) Exciter. (3) Transformer 6000/60000 volts. (4) Differential relay. (5) Potential transformer. (6) Current transformers. (7) Drop shutter relay. (8) Circuit of miniature switches. (9) Circuit of pilot lamps. (10) Isolating switch. (11) Pilot lamp. (12) Automatic oil immersed circuit breaker. (13) Contactor. (14) Coils. (16) Synchronising busbars. (17) Auxiliary busbars. (18) Main busbars. (20) Overload relay. (21) Alarm bell. (22) Feeder. (23) Main regulator. (23a) Pilot lamps for end position. (24) Field switch. (25) Tirrill regulator. (26) Push button switch. (27) Change-over switch. (28) Shunt circuit. (29)—(30) "Closed"—"Open". (31) Speed control. (32)—(33) "Raise"—"Lower". (34) Synchronising plugs. (35) Main busbar circuit breaker. (37) Pressure control. (38) Auxiliary busbars for exciter. (39) Busbars for control circuits. (40) Measuring instruments.

Fig. 2. Arrangement of mimic busbar system, such as adopted for control panels at the Gennevilliers power station.

As soon, however, as operations have to be carried out which do not form part of the ordinary routine, their performance is no longer so easy: this is, in particular, the case when the isolating switches have to be operated in the switch house, a contingency which arises, for instance, when individual sets have to be changed over from one busbar system to another, or cut off from the busbars or from a certain section of the distribution network. Under such conditions, it is difficult to get a full grasp of the mode of connection of the various busbar systems, etc., and, even though the gear may be numbered, frequent disturbances in service may result from errors in switching. When, for instance, the supervising engineer or the relieving switchboard attendant coming on duty wishes to make himself acquainted with the way in which the various sections of the network are connected, he is obliged to go through the whole switch house and get this information with the help of the diagram of connections.

Such were the considerations that led to the idea of providing, in the control room, a simplified diagram of connections, known as a "mimic busbar system", where signalling devices indicate automatically which of the different switches and circuit breakers are "on" or "off". Various types of mimic busbar systems have been devised. One design has recourse to the use of green and red lamps for indicating whether the switches or circuit breakers are open or closed. The clearness of such a mimic busbar system is, however, somewhat impaired by the many lamps alight, as the latter have a rather disturbing effect. A more satisfactory design is that where magnetically operated position indicators are utilised for showing whether the gear they correspond to is open or closed. All these types of mimic busbar systems, however, only serve to give a representation of the conditions of operation at the time, and cannot be used for controlling the switching process.

The design of mimic busbar systems evolved by the Oerlikon Company differs from those mentioned above in that it provides a means of controlling the switching process itself. With the arrangement in question, it is possible to direct from the control room such operations as the changing over of a set from one busbar system to another, for instance, as a pilot lamp becomes alight, both on the switch and on the mimic busbar system, whenever an alteration in connections is made, either in the switch house or in the control room. Changes in connections can thus first be considered on the mimic busbar system; once they have been found correct, the gear itself can be operated in the switch house. The fact that the apparatus in question will be indicated by a lighted lamp, eliminates all possibility of a switching error. The

mimic busbar system thus provides a means not only of checking the connections but also of ensuring that the switching operations are correctly carried out; this is a great advantage specially in the case of disturbances in the system when the staff may be somewhat pressed. The following are vided on the corresponding apparatus in the switch house, the mode of connection being such that both lamps are out when the miniature switch and the apparatus it represents are in the same position. As soon, however, as the position of the gear in the switch house, which may be actuated by hand

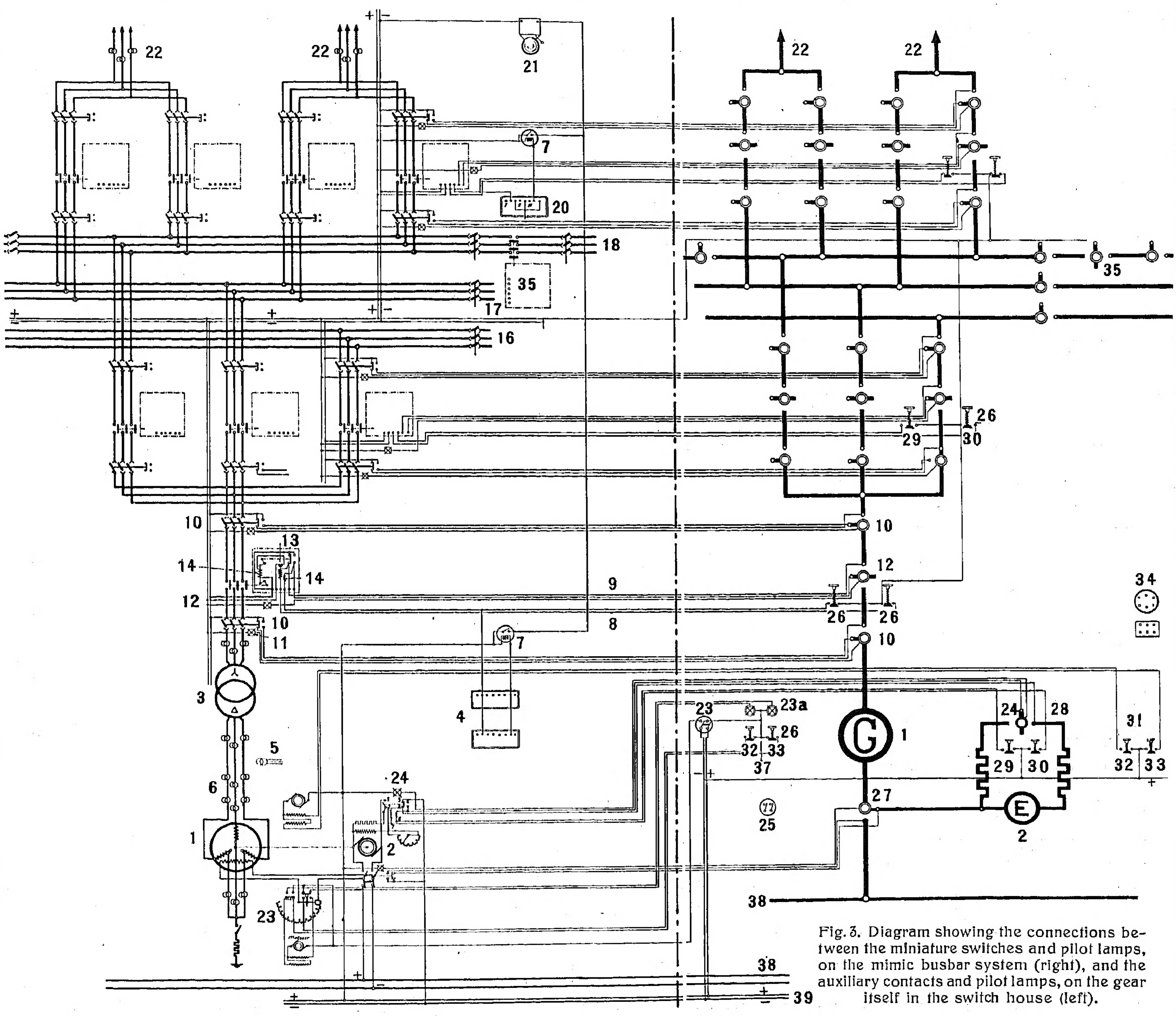
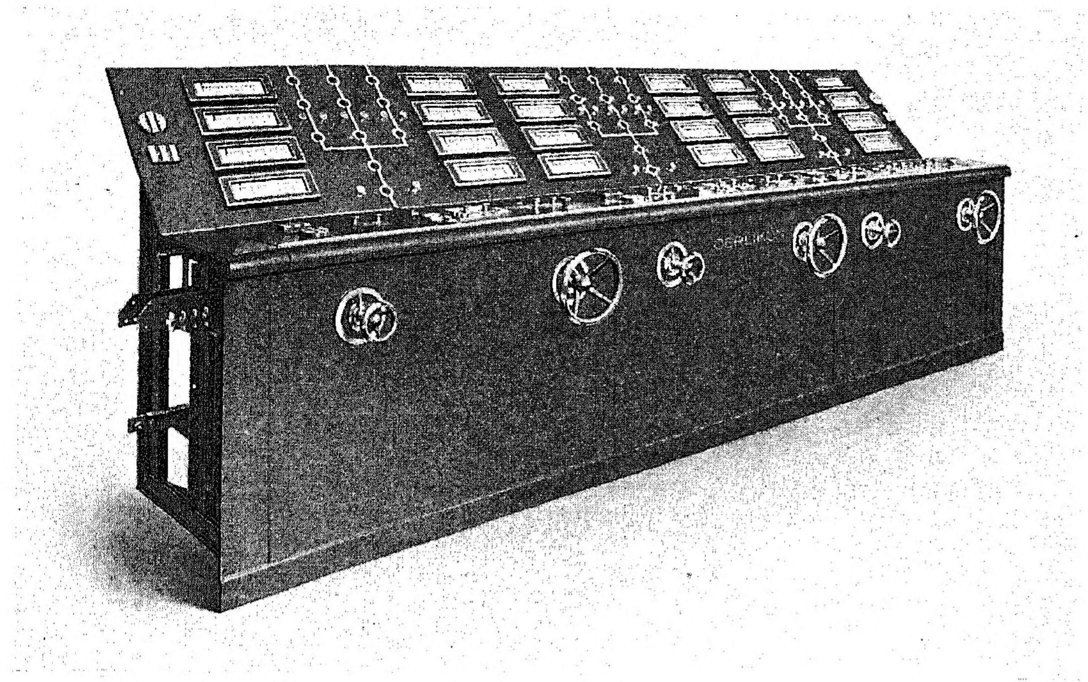


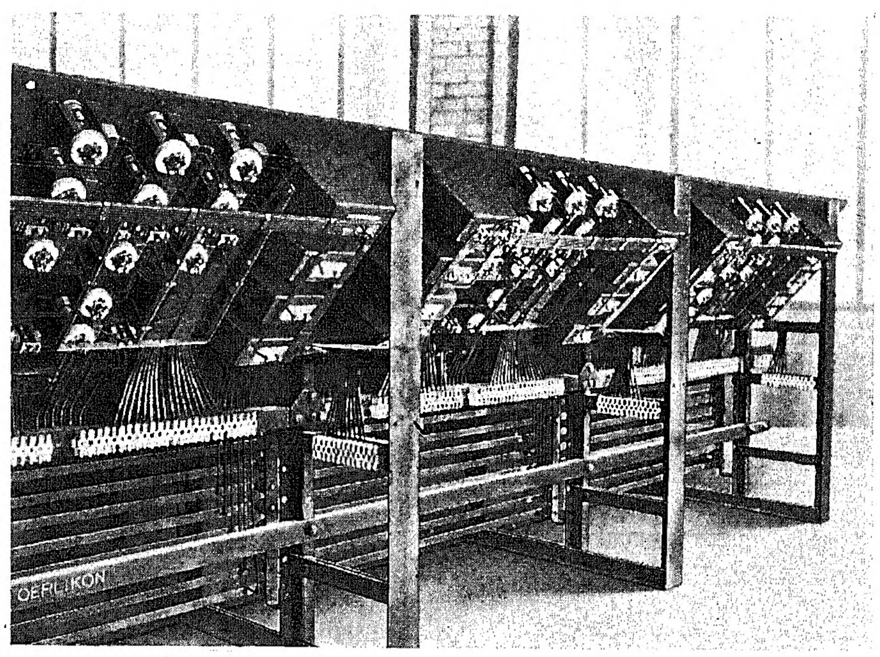
Fig. 3. Diagram showing the connections between the miniature switches and pilot lamps, on the mimic busbar system (right), and the auxiliary contacts and pilot lamps, on the gear itself in the switch house (left).

a few particulars regarding the arrangement of the mimic busbar system and the manner in which it is used.

The mimic busbar system is disposed on the switch desk or switchboard of the installation or in the office of the supervising engineer. Each isolating switch or circuit breaker is indicated by a miniature switch with pilot lamp, arranged in series with the auxiliary contacts and the pilot lamp pro-

or by push button, is no longer the same as that of the corresponding miniature switch on the mimic busbar system, both pilot lamps become alight. If the apparatus in question is now operated, both lamps will be extinguished; this will be an indication that the gear in the switch house and the miniature switch on the mimic busbar system are in the same position.





With this design of mimic busbar systems, the supervising engineer can obtain a full grasp of the mode of connection of the whole installation; nothing can escape him. Any change in the working conditions is immediately brought to his notice through a lamp becoming alight at the corresponding point of the mimic busbar system, so that he can, while remaining in the control room, take the necessary measures to meet the case. Such an installation can be operated in either of the following ways:—

1) The supervising engineer may be responsible for all the switching operations outside the ordinary routine. In this case, the mimic busbar system is arranged in his own office; the necessary changes of connections will be made by him there, and the switchboard attendant will be instructed to switch on or off the gear on which the pilot lamp has become alight. Immediately the attendant has carried out the necessary operation, the pilot lamp on the mimic busbar system will go out, this being an indication for the supervising engineer that the apparatus in question is in the correct position.

2) The switchboard attendant may have to carry out all switching operations, whether they are part of the ordinary routine work or not. In such a case, the mimic busbar system is disposed on the switch desk or switchboard. The attendant alters then the connections on the mimic busbar system, before he operates the gear itself. With this arrangement, the push buttons for controlling the circuit breakers are fitted next to the miniature switches.

Figs. 2 and 3 represent the mimic busbar system designed for generator and feeder panels at the large Gennevilliers power station near Paris. Fig. 2 shows the actual arrangement on the switchboard, while Fig. 3 gives the connections between the miniature switches and pilot lamps, on the mimic busbar system, and the auxiliary contacts and pilot lamps, on the gear itself in the switch house. In order to render the mimic busbar system clearer, the miniature switches and the pilot lamps are combined together.

As the pilot lamps are not alight during normal service, they have a very long life. On the other hand, should either of the pilot lamps of an apparatus fail, for any reason, the fault will be detected immediately the gear has to be operated again, as its two pilot lamps will not become alight; this will indicate that one of the two lamps is out of service and will permit of its rapid replacement. Figs. 4 to 6 are different views of a switch desk with mimic busbar system, for the control of generators.

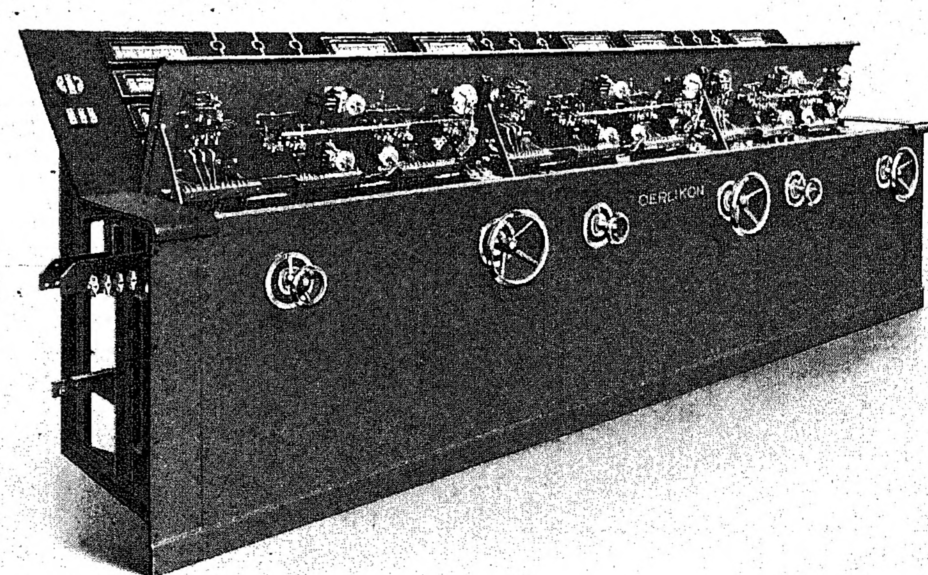


Fig. 4—6. Views of switch desk with mimic busbar system.

BULLETIN OERLIKON

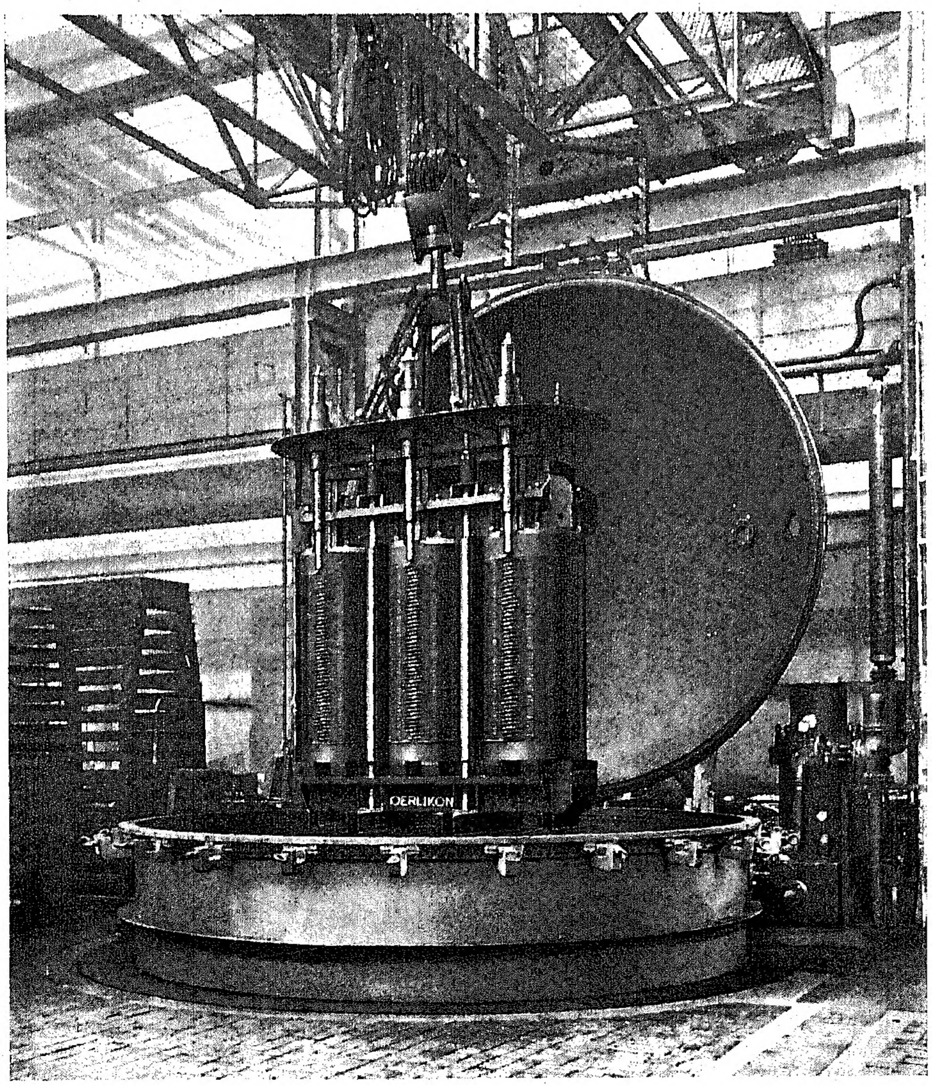
No. 56/57 — February/March 1926

Contents:

Improvements in the Process of Purifying Insulating Oils. By Dr. Boller.

See also article under the same heading in the Bulletin de l'Association Suisse des Electriciens, No. 4, 1925.

Users of insulating oils have, for a long time, felt a need for a method of purifying oil, such as would permit of the rapid and thorough treatment of oil, without affecting its properties. Up to now, it was the practice to remove the solid particles in the oil by means of a filter press, and the water by heating the oil to a temperature of 212 to 230° F. These methods, however, meet only partially the requirements. It is, no doubt, possible through the mere process of filtering the oil to remove not only the finest solid particles, but also the water mixed with it or existing in the form of minute drops. This method of purifying the oil is, however, only satisfactory when very low filtering speeds are adopted and the filter is often renewed. In view of this, the use of filtering plant has been confined to the removal of solid particles, the water itself being removed by the drying-out process. If the drying-out takes place in vacuum, there can be no great objection to this process, though it must be borne in mind that a certain increase in the viscosity of oil is inevitable. Unfortunately, the heating in vacuum is not always possible; the drying-out process is then highly unsatisfactory, as all oils, when heated to a temperature of 212 to 230° F, in contact with air, undergo, after a short time, a noticeable oxidation. Of course, sludging starts earlier with oil treated in such a way.



New drying-out installation for transformers, in the erection shop of the Oerlikon Company. See notes on "Drying-out of transformers", on pages 239/240.

For several years, attempts have been made, in many quarters, to purify oil by subjecting it to centrifugal action in special separators. The design of this class of plant has been so improved that efficient separators can now be had, which are capable of purifying the oil to a very considerable extent, in the shortest time. As the tests carried out by the Association Suisse des Electriciens had demonstrated the practicability of this process*) the Oerlikon Company decided to introduce it in their Works. The separators used are De Laval centrifugal purifiers with a delivery of 88 galls. per hour and 220—264 galls. per hour, respectively.

For the purpose of comparing the filter press method with the centrifugal process, 11-gallon samples were drawn from a large volume of ordinary commercial transformer oil and tested as follows:—

a) in original state.
b) after being treated once in the separator.
c) after being treated twice in the separator.
d) after being filtered once.
e) after being filtered twice.

For the centrifugal treatment, use was made of the separator rated for 88 galls. per hour, the plant being adjusted, in the case of both b) and c), for 66 galls. per hour. For the filtering process, a standard filterpress rated for 220 galls. per hour was uti-

*) Bulletin de l'Association Suisse des Electriciens, No. 6, 1924, p. 297.

lised, this plant being also adjusted, in the case of both d) and e) for 66 galls. per hour.

The oil, in its original state, was fairly dry. In order to be able to form an opinion as to the efficacity of the two processes for the treatment of damp oils, a large quantity of the same oil was sprayed with water, for a considerable period, with a finely perforated rose. At the end of this operation, there remained, after the larger drops of water had settled, a stable emulsion of uniform density. Two 11-gallon samples were then drawn off and tested as follows:—

f) after being treated twice in the separator.

g) after being filtered twice. The adjustments of separator and filter press were the same as before. The various samples were tested with regard to the disruptive strength of oil. The results of these tests are given in table I.

Table I. Disruptive strength of oil, between spheres .49 in. (12.5 mm) in diameter and .197 in. (5 mm) apart (average values obtained for 6 tests).

Sample	Condition of oil	Disruptive strength immediately after treatment, in volts (r. m. s. value)	Disruptive strength one month after treatment, in volts (r. m. s. value)
a	In original state	59400	57700
b	Once through separator	55500	49200
c	Twice through separator	64700	60000
d	Once filtered	46900	44000
e	Twice filtered	51800	45500
	After spraying with water:		
f	Twice through separator	49700	44300
g	Twice filtered	26600	22000

The above figures show the great superiority of the separator over the filter press, specially for purifying very damp oil.

Soon after the introduction of this process, serious doubts were expressed in the technical press as to the efficacity of separators for purifying oil. It was asserted that the high values of disruptive strength obtained for oil treated by the centrifugal process were merely due to the elimination of filaments, etc., while the water itself was only removed insofar as it existed in the form of drops not too minute in size; the smallest drops and more especially the water mixed with the oil, which could amount to as much as 1 ‰, remained necessarily in the oil. Furthermore, it was said that oil, when treated in a separator, was brought into much closer contact with the oxygen of the air than with any other process. The danger of oxidation was thus much greater with this method of treatment. In view of this, the Oerlikon Company deemed it important to ascertain how far these objections, quite plausible in theory, were supported by facts. This could only be done by subjecting the oil to analytical tests, with a view to separating the impurities contained in it, i. e., in the present case, the water and gases. Investigations on these lines were carried out for the first time in the chemical laboratories of the Oerlikon Company. For the purpose of these tests, use was made of the same oil samples as had been utilised for compiling the table I. As stated before, the amount of water as well as the quantity of gases contained in the oil were measured. The results obtained in the case of the various samples are indicated in the table II.

It was found that, by treating the oil in the separator, the quantity of gases in the oil was actually increased.

Table II.

Sample	Condition of oil	Quantity of gases per 3.65 oz. (100 gr.) of oil at 32° F and 30 ins. of mercury	Amount of water in ‰
a	In original state	.572 cu. ins. (9.37 cm^3)	0.039
b	Once through separator	.606 „ „ (9.92 „)	0.034
c	Twice through separator	.648 „ „ (10.60 „)	0.033
d	Once filtered	.58 „ „ (9.49 „)	0.036
e	Twice filtered	.579 „ „ (9.48 „)	0.035
	After spraying with water:		
f	Twice through separator	.585 „ „ (9.57 „)	0.034
g	Twice filtered	.547 „ „ (8.96 „)	0.081

The gases extracted were also tested with regard to their composition. The results obtained were as follows: —

24.5 to 25 % oxygen + 75.5 to 75 % nitrogen.

The proportion of oxygen in air rose to a limited extent, owing to the higher solubility of this gas in oil. If the quantities of oxygen are expressed as percentage of the weight of oil, it will be seen that the amounts in question are very small. In the original state of oil, the 3.65 oz. (100 gr.) contained .572 cu. ins. (9.37 cm^3) of gases; as the proportion of oxygen is 25 %, this represents .143 cu. ins. (2.34 cm^3), the weight of this oxygen being .000203 oz. (.00332 gr.). The quantity of oxygen contained in the oil in its original state thus figured as .00332 % of weight. The oxygen in the oil treated twice in the separator, determined in a similar way, amounted to .00376 % of the weight. The increase in oxygen due to the centrifugal process was thus .00044 %. It cannot be assumed that this small addition of oxygen can reduce the quality of oil in a noticeable way. The suggestion could be made that these .00044 % do not represent the whole quantity of oxygen incorporated in the oil as a result of the centrifugal process, as the quantities retained by chemical absorption or oxidation can amount to much more. It can, however, be pointed out, in this connection, that the oxidation of oil at the temperature of 105° F. at which the centrifugal process is normally carried out must take place exceedingly slowly. On the other hand, the oil is only subjected to the stream of air, in the separator, for a short time; consequently, a marked oxidation is practically out of the question.

The quantity of water in oil vary approximately in the same manner as the disruptive strength in table I. According to the tests, the value .033 ‰ seems to be the upper limit, when purifying oil by the centrifugal process. When the oil contains, in its original state, a quantity of water fairly near that value, as was the case for the first tests, there is no great difference between the two processes as regards efficacity. In the case of oil sprayed with water, however, the centrifugal process proved far superior. As regards the oil filtered twice, it remained milky though the filter had been renewed after the first filtering operation; the oil did not even become clear, after standing several weeks. The oil treated in the separator was, on the other hand, perfectly clear after the first centrifugal operation. Some of this oil was placed in a sealed jar and left in the open for several months (late autumn to winter); even after this period, no clouding of oil could be observed.

The above investigations thus show that, as a result of the introduction of centrifugal purifiers, a further valuable process has been added to the existing methods of removing the moisture and solid particles from insulating oils.

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The Induction Regulator as used for Power Factor Regulation in Interconnected Systems.

The practice of interconnecting power stations is becoming more and more general every year. In the case of Switzerland, for instance, this process has been applied on an extensive scale, and power stations of all sizes have been interlinked far beyond the frontiers of that country, so as to permit of their supplementing each other when required.

In order to be able to connect up two generating stations, the following conditions have to be satisfied: firstly, the terminal pressures of the two power stations must be in phase, and secondly the pressures of the two installations must have the same value at the point of connection. Compliance with the first condition does not present any difficulty, as synchronism sets in automatically. If the second condition is also satisfied, each power station has only to supply its own wattless component. Should, however, fluctuations in pressure occur, owing to the unavoidable pressure drop in the interconnecting line and in the transformers which are necessary, for instance, when interlinking power stations with different pressures, this condition can no longer be complied with. As a result, the distribution of the wattless K.V. A. between the two generating stations varies with the load; this can, however, be avoided by providing a pressure regulator in the interconnecting line. In certain cases also, it may be desired that the wattless load should be transferable at will from one power station to the other, without having to vary the excitation of generators; this can be done too by inserting a pressure regulator in the interconnecting line.

Such duties are best performed by an induction regulator, as with this type of plant the pressure can be adjusted, without jerk, for any desired value within the range of regulation of regulator. It is, of course, no longer possible to speak here of an actual regulation of pressure, as the pressure regulation is only the means for transferring the wattless load from one system to the other or for preventing the wattless load of one power station from shifting to the other. The induction regulator thus acts, here, as a phase displacer.

We now propose to describe, as briefly as possible, the manner in which the wattless load is displaced by an induction regulator. As the interconnection of A. C. installations is comparable with the connection of individual generators to common busbars in the same power station, and the conditions ruling the distribution of the actual load and the wattless K.V. A. are the same, we shall consider, for the sake of simplicity, the case of two generators in parallel.

1. Regulation of the actual load or power component.

If two generators A and B of identical design are rigidly coupled together, in such a way that the poles of same name of these machines coincide exactly with each other, and excited to an equal extent, their terminal pressures will have the same value and be in phase (see Fig. 1); in such a case, no current will flow through the windings, when the generators are connected in parallel. Should, however, the rotors of the two generators be coupled together in such a manner that the poles of the same name are at an angle φ in relation to each other, there will be a phase displacement φ between the pressures of A and B (see Fig. 2), which causes a difference in pressure C. If the two generators are now connected in parallel, this pressure C gives rise to a circulating current i in the windings of the two generators. Let us designate this current by i_a in the generator A and by i_b in the generator B. As can be seen from Fig. 3, this current has, in the generator A, a direction opposed to that in the generator B. On the other hand, as the reactance of the generator windings greatly exceeds their ohmic resistance, this current has a phase displacement of nearly 90° in relation to the pressure C which produces it; consequently, the current vectors i_a and i_b are to be set out in the pressure diagram of Fig. 2, as shown in Fig. 4. The latter diagram shows that the currents i_a and i_b are nearly in phase with the pressures A and B, so that a torque comes into play. The generator A, which leads over the generator B, works as a generator and supplies current to B, which itself operates as a motor. Such a mode of operation is not permissible, as, in such a case, the loads of the generators would not be symmetrical owing to the circulating current.

Let us now assume that the two generators are driven by identical turbines and that the two generators are suddenly uncoupled. The result will be as follows: the generator A, which works as a generator, will tend to slow down, while the generator B, which operates as a motor, will have a tendency to increase its speed, until the two generators are in phase. The circulating current i will, at the same time, disappear and the generators will run as parallel-connected machines on light load. Should the two generators be put on load, with exactly the same excitation and with the throttle valves of the turbines opened to the same extent, each generator will take over exactly half the wattless and power components. Fig. 5 shows how the total load is distributed between the generators A and B.

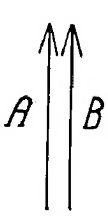


Fig. 1.

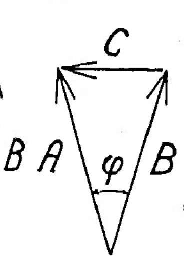


Fig. 2.

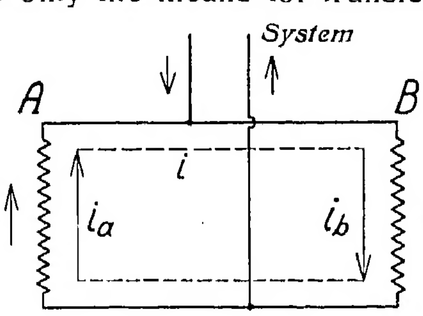


Fig. 3.

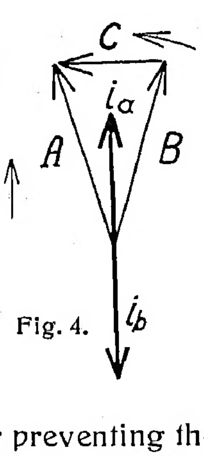


Fig. 4.

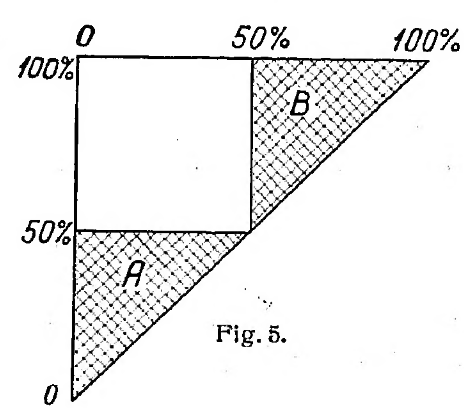


Fig. 5.

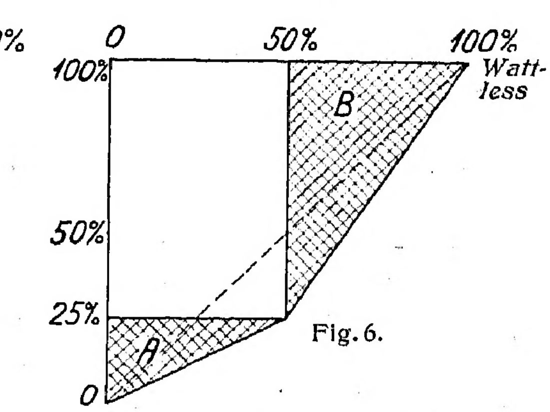


Fig. 6.

If the throttle valve of the turbine of generator B is further opened so as to correspond, for instance, to $^3/_4$ load and the admission of steam of the turbine driving generator A reduced to that for $^1/_4$ load, the distribution of load will be as shown in Fig. 6. During the adjustment of the throttle valve of the two turbines, the generator B, owing to the larger admission of steam, will tend to accelerate and assume a leading phase displacement in relation to generator A, while the latter has a tendency to slow down, owing to the smaller admission of steam; consequently, a circulating current i will be produced, as stated above, which causes a reduction of the speed of B and an increase of the speed of A, until the two generators are again in phase. The generator B takes over now three quarters of the total load and the generator A, one quarter. The wattless KVA has, however, remained the same for both machines, as the excitation of the generators has not been altered.

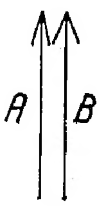


Fig. 7.

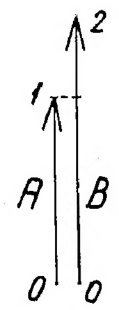


Fig. 8.

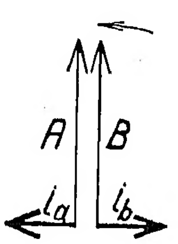


Fig. 10.

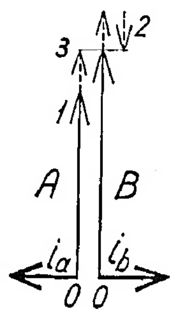


Fig. 11.

2. Regulation of the wattless component.

We have seen in Section 1 that, when two generators A and B of identical design, driven independently, are connected in parallel and given exactly the same excitation, their pressures have the same value and are in phase; as long as no load is on, no current flows through the windings of machines (see Fig. 7). If, however, the generators, while on light load before being connected in parallel, are excited unequally, in such a way that the pressure of A is 0—1 and the pressure of B, 0—2, as in Fig. 8, a difference in pressure 1—2 results. Should the two generators be connected now in parallel, this difference in pressure 1—2 gives rise to a circulating current i. According to Section 1, this circulating current must be plotted at right angle with the pressure which produces it. Fig. 8 shows that the pressure 1—2 is in phase with the terminal pressure so that the circulating current is also at right angle with the terminal pressure. We are designating again by i_a and i_b the circulating current in generators A and B, respectively. As will be seen, this circulating current has in generator B the opposite direction to that in generator A and is thus leading in generator A and lagging in generator B (Fig. 10).

As the two generators are connected to the same busbars, their terminal pressures must be equal. In the present case, the terminal pressures will assume an average value 0—3, when the generators are paralleled, as both machines are here identical; the leading current i_a in generator A will raise the pressure 0—1, while the lagging current i_b in generator B will lower the pressure 0—2, as indicated in Fig. 11. As the circulating current is only a wattless current, it cannot produce a torque and, consequently, cannot affect the phase angle between the two generators, neither cause any displacement of load from one generator to the other. This means that the variation of excitation only permits of the transfer of the wattless KVA from one generator to the other.

Let us consider once more the first example where it has been assumed that the total output of the installation is distributed evenly between the two generators working in parallel (see Fig. 12). For such conditions of operation, it is necessary that the turbines should be set for the same output and the generators excited equally. If the excitation of the generator A is now reduced, and that of the generator B left unaltered, the total load will apportion itself between the two

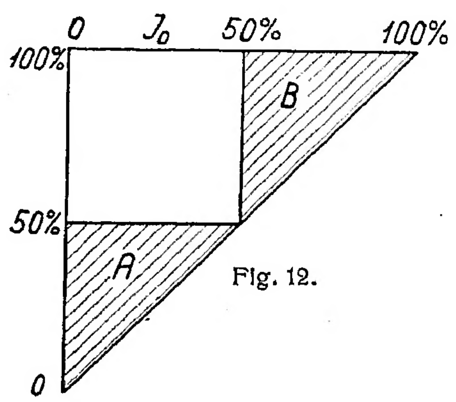


Fig. 12.

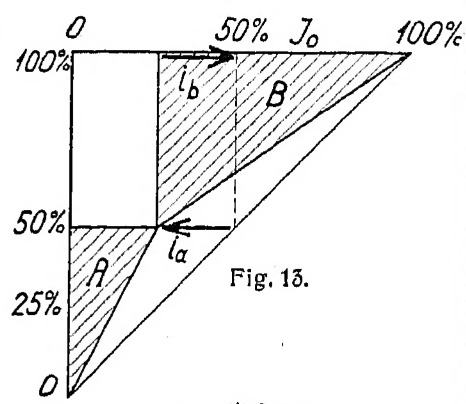


Fig. 13.

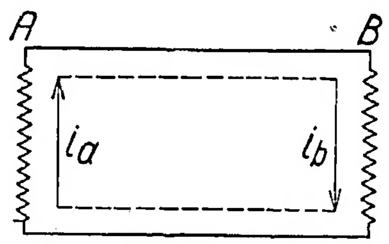


Fig. 9.

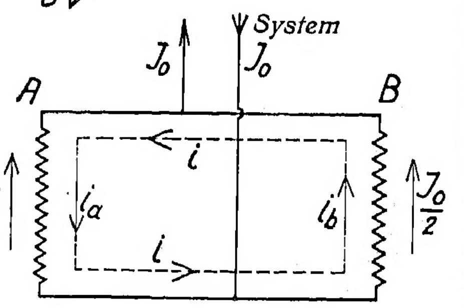


Fig. 14.

generators as shown in Fig. 13, for instance. As the generator A is less excited than the generator B, or, in other words, as the pressure of A is smaller than that of B, this will give rise to a wattless circulating current which equalises again the pressures of both generators, as indicated above. This circulating current flows through the winding of generator A in the opposite direction to that through the winding of generator B (see Fig. 14). The wattless current J_0 of the system has, however, in both generators, the same direction, as shown in Fig. 14. In view of this, the circulating current i_a in generator A compensates a corresponding portion of the wattless current J_0 of system, while the circulating current i_b adds itself arithmetically to the wattless current J_0 of system, as shown in Fig. 13. The generator A runs now with a better power factor and generator B with a worse power factor; the total power factor of the installation remains, however, the same.

It is thus possible, by regulating the excitation, to displace the wattless K.V.A. of an installation, at will, from one generator to the other, provided the generators in question are in position to take over the increased wattless load. The generator which is less excited and has the lower pressure takes over the smaller share of the total wattless load, while the machine which is more excited and has the higher pres-

sure takes over the larger share. The power component cannot be influenced by varying the excitation of the generators. The above applies also to power stations working in parallel; it is, however, necessary, in the latter case, to take into account the pressure drop in the interconnecting line, as well as that in the transformers in the line.

Interconnection of two power stations.

Let us now consider the case of two identical power stations A and B linked up by an interconnecting line L without capacity, and working on common busbars S arranged in the power station B, as shown in Fig. 15. For the sake of simplicity, we shall assume that each installation is only equipped with one generating set, so that our study is reduced to that of two generators operating in parallel.

At light load and with the generators equally excited, the pressures A and B are in phase and have the same value (Fig. 16); in such a case, no current flows through the system. If a load G with a power factor unity, for instance, is applied in H, this load apportions itself evenly between the generators A and B, provided the throttle valves of the turbines are opened to the same extent.

We now propose to show the effect of the transmission line, with its reactance and ohmic resistance, on the parallel operation of generators. The current J flowing through the line L causes an ohmic drop J_r and an inductive drop J_x, so

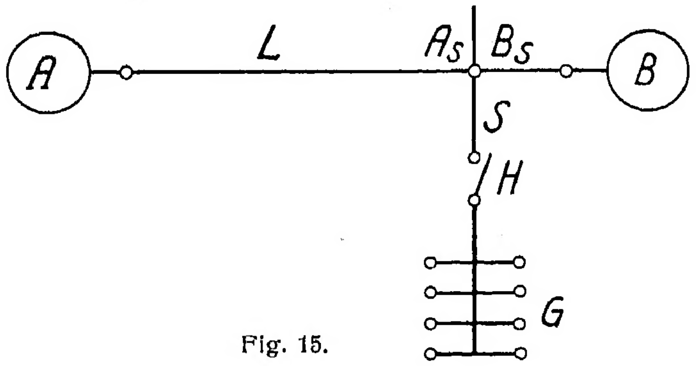


Fig. 15.

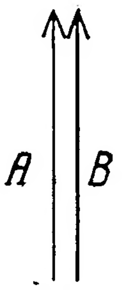


Fig. 16.

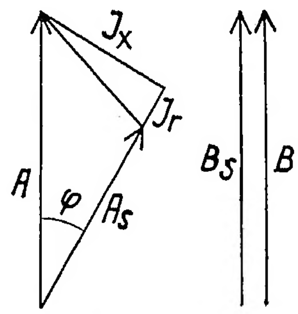


Fig. 17.

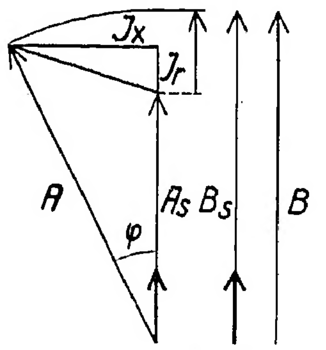


Fig. 18.

that the pressure at the point A_s is no longer in phase with the terminal pressure of the generator A, while the pressure B_s is still in phase with the terminal pressure of the generator B. Fig. 17 represents the conditions in system, but only at the instant the load G is applied. The difference in phase between A_s and B_s gives rise to a circulating current which causes the displacement of the generators in relation to each other, until A_s is in phase with B_s, as described in Section 1. Fig. 18 represents the normal conditions of operation after these adjustments have taken place.

It will be seen from the diagram in Fig. 18, that A_s is actually in phase with B_s but, owing to the pressure drop in the line L, A_s is much smaller than B_s; this results in a circulating current, as shown in Section 2, which causes the generator B to take over a wattless load. If the terminal pressure of generator A is raised, by increasing the excitation until the pressure at A_s is equal to B_s, the circulating current disappears and the generator B then works with power factor unity. Under such conditions, the generator A operates with a lower power factor than unity, as can be seen from Fig. 18; this machine has now to supply the wattless KVA caused by the pressure drop in the line L. This power factor corresponds to the angle φ in Fig. 18. The phase displacement depends upon the current which flows through the line L, upon the ohmic resistance and the reactance, and upon the power factor of load.

In the present example, where we have assumed that the two power stations are working on the same busbars, all the necessary conditions for the satisfactory parallel operation of these installations can be complied with, as the excitation of generators can be adjusted accordingly. When, however, each power station works on separate busbars, which have to be kept at a constant pressure, and power has to be transmitted from one installation to the other, whether it be only from A to B or also from B to A, it is no longer possible to meet the conditions merely by adjusting the excitation. In such a case, a pressure regulator R is provided in the interconnecting line for dealing with the pressure regulation or, more exactly, with the distribution of the wattless load between the two power stations; each power station can then adjust its pressure, independently of the other power station, to suit its load, by varying the excitation of generators. Fig. 19 shows the arrangement corresponding to such conditions.

The induction regulator, as we have already shown, is specially suited for adjusting the distribution of wattless load

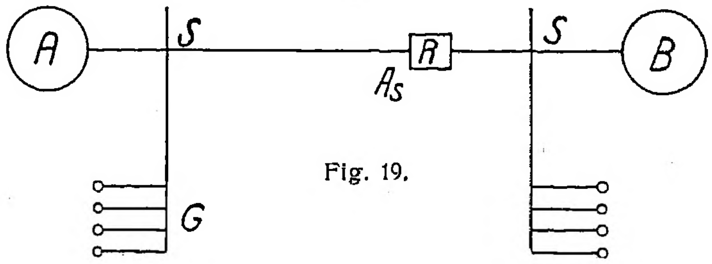


Fig. 19.

in interconnected systems. As, however, the regulated pressure and non-regulated pressure are not in phase in all the positions of regulator, when an ordinary induction regulator is resorted to (see Bulletin Oerlikon No. 30), a relative displacement between the rotors of the generators of the two power stations has to take place, each time the regulator is moved, in order that the pressures at the point of connection of the two power stations should always remain in phase. Fig. 20 shows the relative displacement for a given position of induction regulator. A_s is the pressure of the power station A, at the end of the transmission line, before regulation, R the additional pressure of the induction regulator R, with variable phase according to the position of regulator, and

As_1 is the pressure after it has been regulated to correspond to the pressure in the power station B. The angle φ represents the relative displacement between the rotors of the generators of the two power stations, caused by the additional pressure R for the given position of regulator. The generator of the power station A is thus subjected to a displacement in relation to the generator of the power station B, each time the position of regulator is altered. In the case of regulation by hand, or with automatic control where the regulation is not too rapid, this displacement does not affect the stable operation of the two power stations. When, however, a quick-acting regulator is resorted to, the stability in operation of installations can, under certain conditions, be compromised. We, therefore, recommend, in such cases, the use of double induction regulators, as these are free from all phase displacement between incoming and outgoing pressures, along their whole range of regulation, as can be seen from Fig. 21; in the diagram in Fig. 21, As is the pressure at the end of the transmission line before regulation, $R/2$ and $R/2$ are the additional pressures of the double induction regulator, and As_1 is the pressure after it has been regulated to correspond to B.

Induction regulators of the type in question consist of two ordinary regulators of half capacity coupled together rigidly. The pressures As, As_1 and B are in phase for every regulator position, as can be seen from Fig. 21, where the position of regulator has been chosen arbitrarily; it follows that no relative displacement between the generators working in parallel will take place at any point of the range of regulation of regulator.

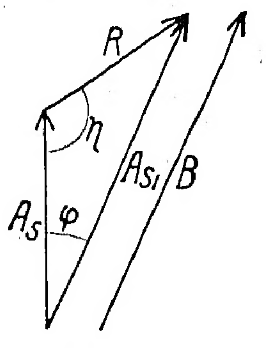


Fig. 20.

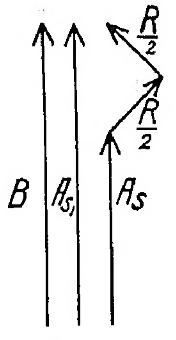


Fig. 21.

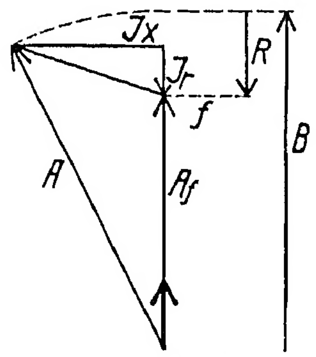


Fig. 25.

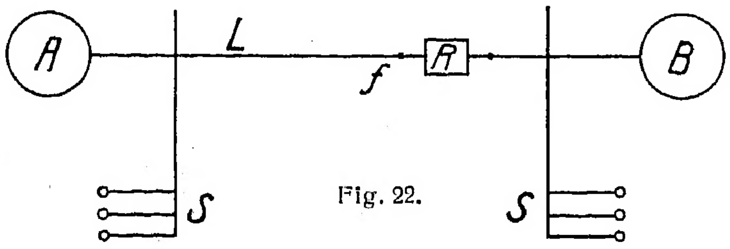


Fig. 22.

Example.

Let us take again the case of two power stations A and B connected in parallel by means of an overhead line L (Fig. 22). These power stations have each their busbars S, which have to be kept at a constant pressure. We shall assume that the power station B wishes to draw energy from A at a power factor .6. As, however, A supplies its power only at power factor unity, for instance, B has to provide, itself, the wattless component of the energy it derives from A. This could easily be done by adjusting the excitation of its generators accordingly, as shown in Fig. 2, if such an alteration in pressure at the busbars was permissible. As, however, this is not the case, in view of the fact that the busbar pressure hs tao remain constant, it is necessary to provide, in the power station B, an induction regulator permitting of the adjustment of the pressure of generators at the point f, at any time, irrespectively of the value of busbar pressure; it is then possible to regulate the pressure B in f, in such a way that it is always equal to the generator pressure A minus the ohmic and inductive pressure drop in the line, for energy drawn at power factor unity (Fig. 25). If these conditions are complied with, the energy drawn from A by B has a power factor unity in f, and A has to supply the wattless K.V.A. due to the pressure drop in the line.

If the power station A can supply the energy at a power factor .8 instead of unity, the regulator must be so dimensioned that, under all conditions of operation, the pressure of B can be regulated in f, in such a way that it is always equal to the generator pressure A minus the ohmic and inductive pressure drop in the line, for energy drawn at power factor .8.

Let us now take a concrete example and assume that the power station B draws from A 5000 KW at power factor unity and that the line has an ohmic pressure drop of 4 % and an inductive drop of 10 %. In order to be able to comply with the condition that the energy is to be drawn at power factor unity, we find that the induction regulator has to reduce the pressure of B by about 4 % at full load. It follows that the internal capacity of the induction regulator must be: $5000 \times {}^{4}/_{100} = 200$ KVA. If, however, the power station A can supply the energy at a power factor .8, the pressure drop in the line will necessitate a pressure regulation of 13 %. As the power passing through the induction regulator is now $^{5000}/_{0.8} = 6250$ KVA, the internal capacity of the regulator will have to be: $6250 \times {}^{13}/_{100} = 815$ KVA.

In the examples considered, the induction regulator can only be utilised over half its range of regulation, namely, on the minus range, as we have assumed that the generators of the two installations are identical and thus have the same pressure. If, however, the power station A can, for instance, raise its pressure to the extent of half the pressure drop at full load, the regulator can be used over its whole range of regulation + and —, as shown in Fig. 24. As a rule, the pressures of two power stations coupled together differ so much that a transformer has to be inserted in the interconnecting line. In this case, the pressure ratio of transformer is to be chosen in such a way that the regulator can be utilised over its + and — range of regulation, without having to adjust the generator pressure accordingly. When fixing the range of regulation of the induction regulator, the pressure drop of the transformer is also to be taken into account.

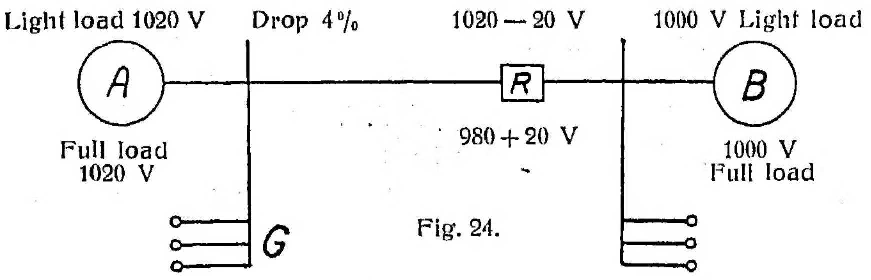
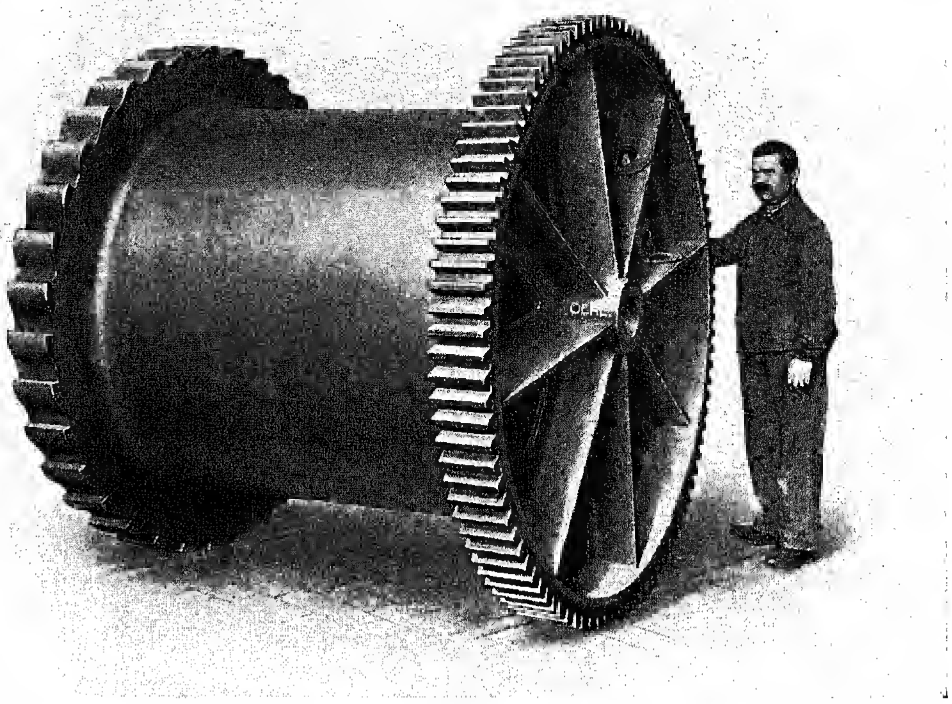


Fig. 24.

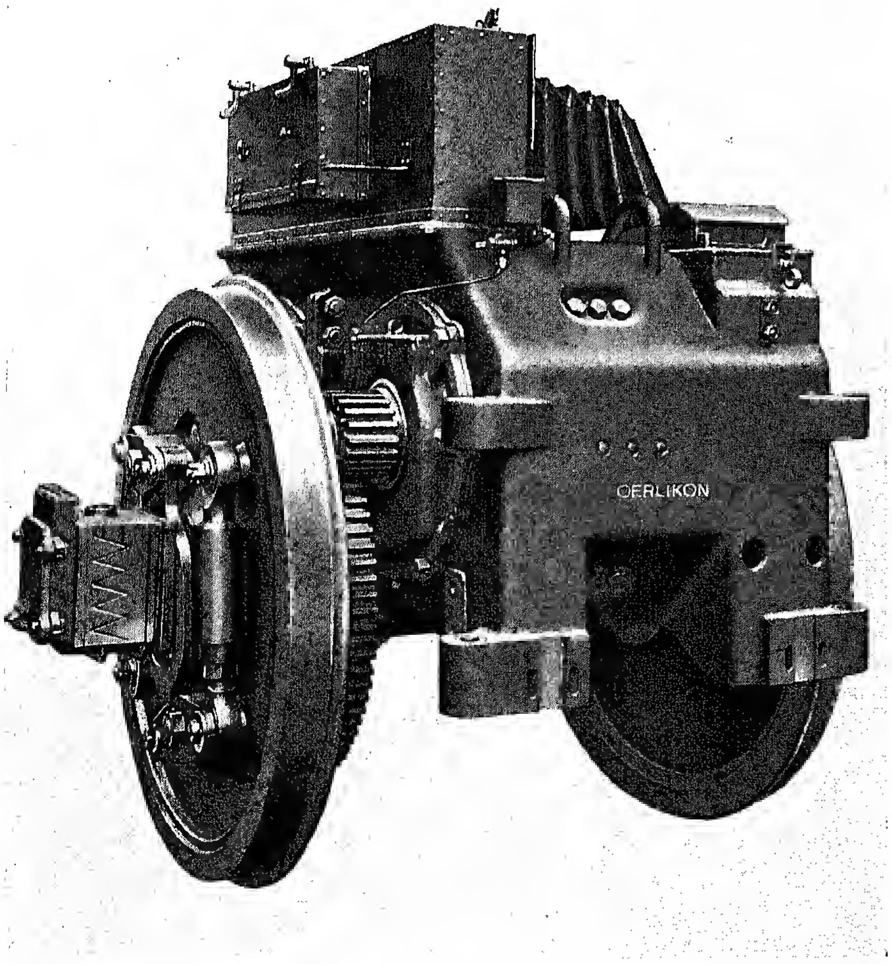
Notes and News Items.

Winding gear for sinking pumps. When sinking new mine shafts or when deepening existing pits, it is often necessary to resort to so-called sinking pumps for extracting the water that collects at the bottom of shaft. These pumps, with their pipes, are suspended to ropes which are carried by winding gear mounted at the mouth of the pit. The dimensions of the drums of such winding gear may be gauged from the illustration given here. The winding equipment in question was supplied to the Société Minière et Métallurgique de Penarroya. The drum is subjected to a load of about 10 tons, and can take about 2030 ft. of rope, the latter having a diameter of $1^3/_8''$ (34 mm).



Drum of winding gear for sinking pump.

Electric trials on the Paris, Lyons and Mediterranean Railway. At the end of September of last year, the Oerlikon trial locomotive, type 2BB2, supplied to the above Company was subjected to exhaustive tests both as regards running and regenerative braking. This locomotive has an output of 2400 HP at 31 m. p. h. and a maximum speed of 68 m. p. h. The trials were entirely successful and the locomotive has now commenced its period of guarantee. The running tests covered the whole range of operation of the locomotive up to the highest speed and maximum load. The trials with regenerative braking were also carried out under the most varied speed conditions and the stipulations of contract in this respect fully satisfied; the latter laid down that the electric braking equipment was to be capable of dealing with a total train load of 500 tons, including a weight of locomotive of 120 tons, on a gradient of 1 in 33, the speed being maintained at 22 to 25 m. p. h. During these tests a current of 600 amps. at 1500 volts was fed back into the system with the train travelling at 25 m. p. h.



View showing assembly of the twin motor equipments on the locomotive, type 2BB2, of the P.L.M. Railway; each unit is designed for 600 HP (continuous rating).

The method of regenerative braking evolved by the Oerlikon Company for D. C. locomotives and adopted here is, like that devised by them for single-phase railways, characterised by the smooth and reliable regulation of speed obtainable and the steady braking action ensured. The operation of equipment is very simple. When changing over to electric braking, the driver does not have to consult any instruments. The same controller handle which serves for starting up and running is also used for braking; the driver has only to know what grouping of motors is required for the speed at the time.

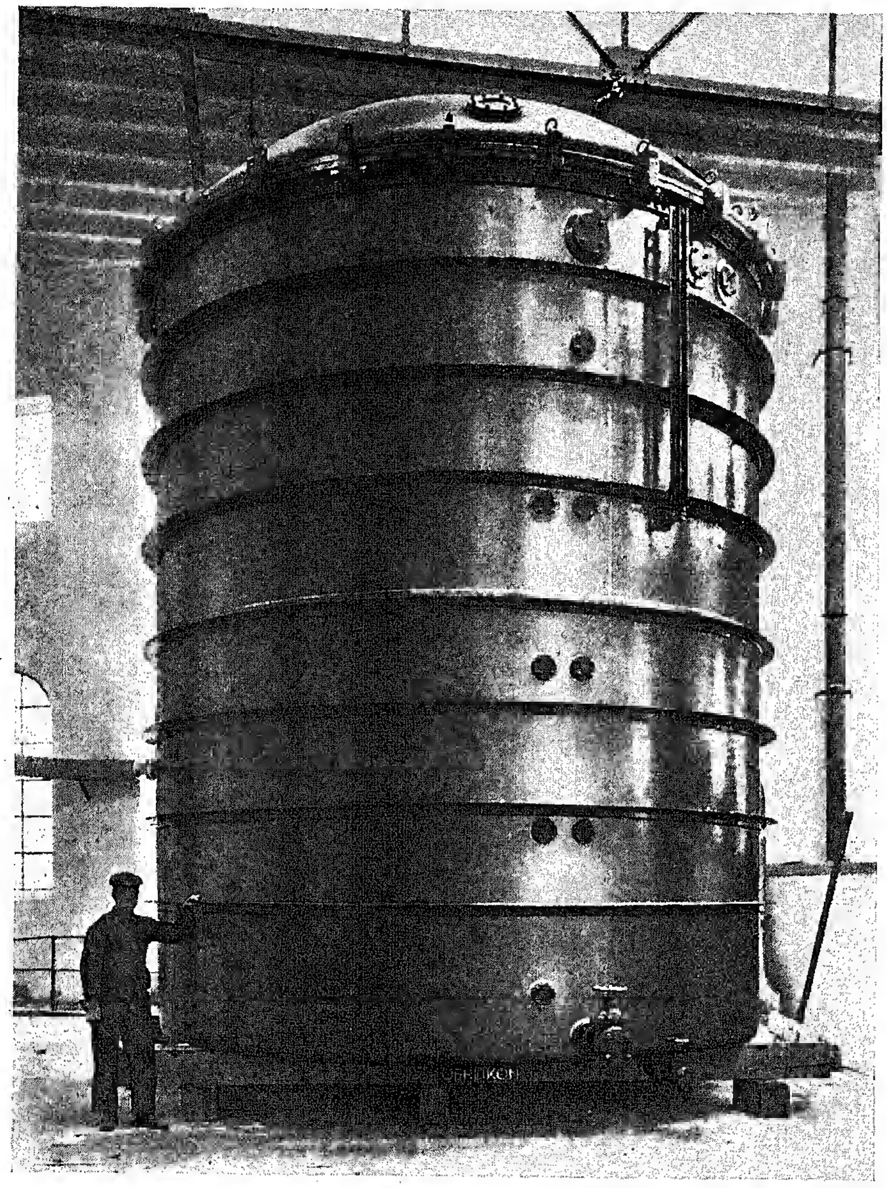
The electrical equipment as well as the control arrangements and general lay-out and also the mechanical part have given entire satisfaction; the latter embodies as notable feature the special Oerlikon articulated coupling for connecting motor to driving wheels (see Bulletin Oerlikon No. 9).

Drying-out of transformers. The drying-out of transformers, and more especially of large units for high pressures, is an operation which calls for great care, as it is a matter of special importance that every trace of moisture and air should be removed from the oil and insulation, in order to increase, as far as possible, their dielectric strength, while, at the same time, all deterioration of oil during the process must be avoided. It may, therefore, be of interest to give a few particulars regarding the arrangement adopted by the

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

Oerlikon Company in the case of the new drying-out installation they have provided at their Works to meet increasing requirements.

The equipment in question comprises a tank capable of accommodating the largest transformers, in which the air is exhausted during the drying-out process by means of a vacuum pump. The heating is obtained either by means of the steam pipes arranged in the tank or by an external heater through which the oil of transformers is forced by a circulating pump. The installation is mainly characterised by its large capacity and high efficiency. The tank itself has a diameter of about 16 ft. and a total height of about 22 ft. The tests carried out on the tank have shown that, in spite of its large dimensions, and the great length of welded joints, a very high vacuum could be attained. The illustration on this page represents the tank itself, while that on page 233 shows the complete drying-out installation in operation. As can be seen, the tank has a circular section, both bottom and cover being dished; the cover is fitted with vacuum gauge and thermometer, in the usual way. Provision has been made for glass inspection windows and electric lighting in the tank, so that the upper surface of oil in the transformer tank can be easily examined during the drying-out process. The cover of tank is hinged and can be raised by means of a motor driven winch. It will be seen from page 233 that the tank is nearly completely sunk in the floor.



Vacuum tank of the drying-out installation, assembled and ready for lowering into position.

The use of steam heating by means of the pipe system in the tank is mainly confined to cases where a number of small transformers are being dried out at the same time. When, however, large transformers with a great heat capacity have to be dealt with, this mode of heating is too slow, owing to the low thermal conductivity in tank, due to the rarefication of air. The transformers are then dried out by causing the oil to circulate through the oil heater provided for the purpose. The latter equipment is of standard Oerlikon design and has a capacity of 100 KW. Owing to the fact that the oil of transformers is heated indirectly in this plant and does not come into contact with the electric heating coils, there is no danger of the oil being over-heated at any point. The oil heater is fitted with safety devices which cut off the heating current when the temperature of oil rises too high, or interrupts the oil circulation. It may further be mentioned that arrangements have been made in order to permit of the heating of oil directly by means of electric resistances, should it be desired to adopt this mode of heating in certain cases, the necessary air-tight bushings being provided on the tank for leading in the current conductors.

As the drying-out process is carried out with a high vacuum in the tank, the circulating pump for the oil heater cannot operate as suction pump, but has to be used as compression pump; consequently, it has been necessary to mount it at the bottom of tank. The oil heater, however, is installed above, on the floor level, on the side of tank. The circulating pump is of the type evolved by the Oerlikon Company for use with transformers with external oil cooling, this plant being specially suited for the present duties. The unit in question consists of a centrifugal pump built as integral part of the driving motor. The pump has no glands and no external moving parts; it requires no attention, works practically noiselessly and is very reliable in operation. The vacuum pump for exhausting the air in the tank is also a pump of the Oerlikon Company's manufacture.

The three-phase transformer which is shown on page 233 in the process of being lowered into the tank is a 6000 KVA unit for 60000/32000 volts, 50 cycles, arranged for external water cooling. This transformer is provided with circular coils with paper insulated conductors, both on the high and low tension side. The completed windings are impregnated with oil-proof insulating paint. The transformer is capable of withstanding, for short periods, a pressure between turns equal to the total supply pressure, at the beginning of windings and near the neutral point, where the insulation is reinforced, and a pressure between turns amounting to 60% supply pressure at the other points of windings. The high and low tension windings are secured independently by powerful springs which compensate any shrinkage during the drying-out process.

The transport of the vacuum tank, from the makers to the Oerlikon Works, was in itself no easy matter. As there could be no question of conveying the tank by rail, owing to the limitations imposed by the railway loading gauge, transport by road had to be resorted to. Even so, the tank had to be sent in two parts, the latter being welded together after arrival on site.

EINPHASEN-SCHNELLZUGS-LOKOMOTIVE TYP $A^{e\,3/6}$

DER SCHWEIZERISCHEN BUNDESBAHNEN

ERWEITERTER SONDERABDRUCK
AUS DER SCHWEIZER BAUZEITUNG, JUNI 1925

MASCHINENFABRIK OERLIKON
OERLIKON

DIE EINPHASEN-SCHNELLZUGLOKOMOTIVE
TYP $A^{e}\,{}^{3}/_{6}$
DER SCHWEIZERISCHEN BUNDESBAHNEN

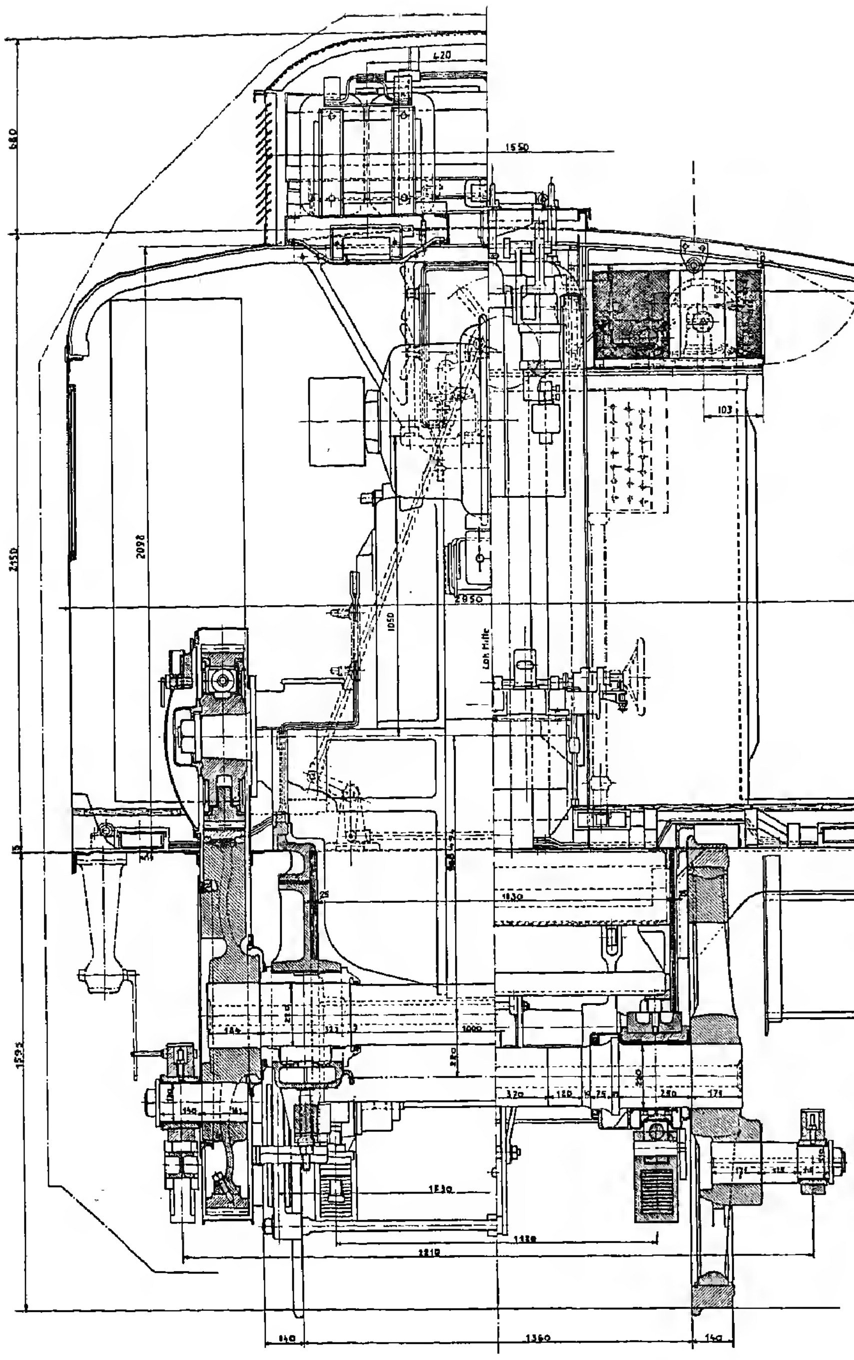


Abb. 4. Querschnitte durch Vorgelege und Triebrad.

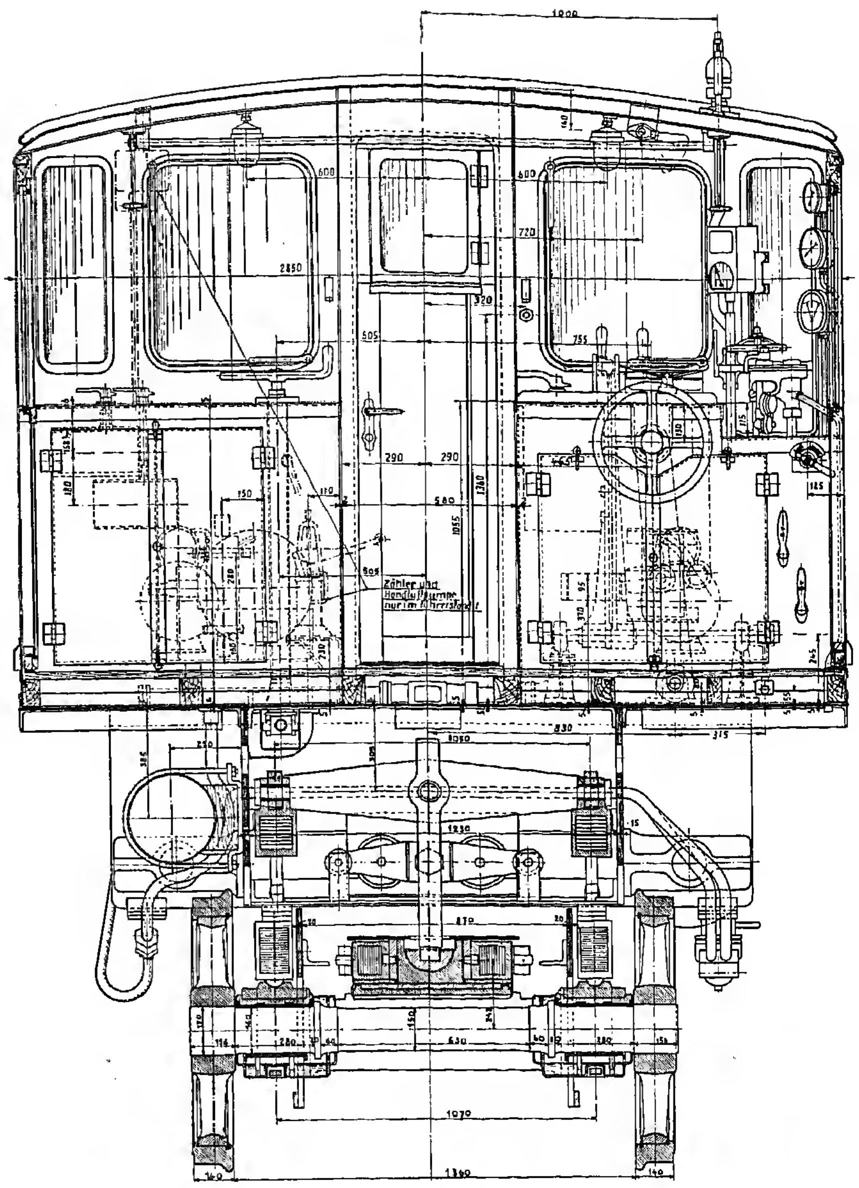


Abb. 5. Querschnitt durch Führerstand und Bisselachse.

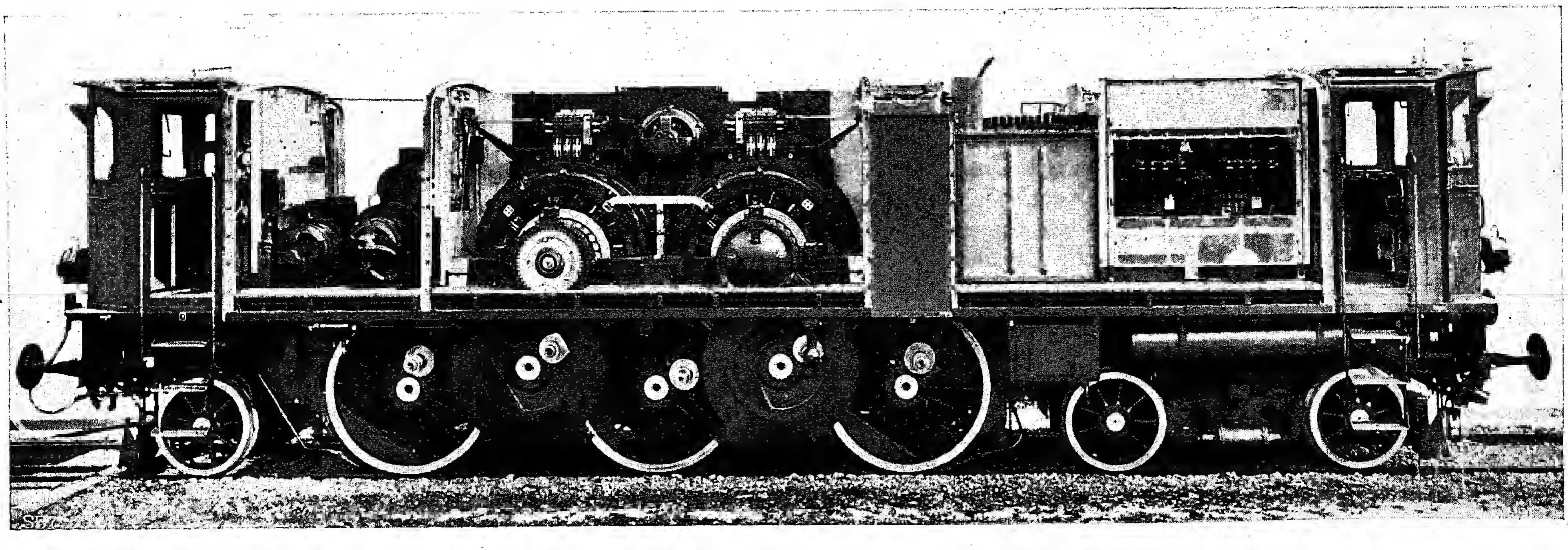


Abb. 9. Ansicht der Lokomotive mit abgenommener Verschalung des Apparatenraumes.

Hauptverhältnisse der $A^{e}3/_{6}$-Lokomotive der S. B. B.

Spurweite	1435 mm	Dauerleistung am Radumfang bei einer Fahrgeschwindigkeit von 70 km/h . . .	1920 PS
Gesamtlänge über Puffer	14090 mm	Stundenleistung am Radumfang bei einer Fahrgeschwindigkeit von 65 km/h . . .	2200 PS
Gesamter Radstand der Lokomotive . . .	10800 mm	Zugkraft am Radumfang bei Stundenleistung	9100 kg
Radstand des Laufachsen-Drehgestells . . .	2150 mm	Maximale Zugkraft am Radumfang	16700 kg
Fester Radstand der Triebachsen	4700 mm	Maximale Fahrgeschwindigkeit	90 km/h
Triebrad-Durchmesser	1610 mm	Gewicht des mechanischen Teils	54,8 t
Laufrad-Durchmesser	930 mm	Gewicht des elektrischen Teils, einschliesslich Stromabnehmer und Kompressorgruppe	40,6 t
Kurbelkreis-Durchmesser	600 mm	Gewicht des Inventars	0,6 t
Uebersetzungsverhältnis der Zahnräder . .	1 : 2,224	Dienstgewicht der Lokomotive	90,0 t
Grösste Höhe des Lokomotivkastens . . .	3750 mm	Adhäsionsgewicht der Lokomotive	56,0 t
„ Breite „ „ . . .	2950 mm		
Fahrdrahtspannung (+ 10 %; − 15 %)	15000 Volt		
Periodenzahl . . . . (± 1/2)	16 2/3		

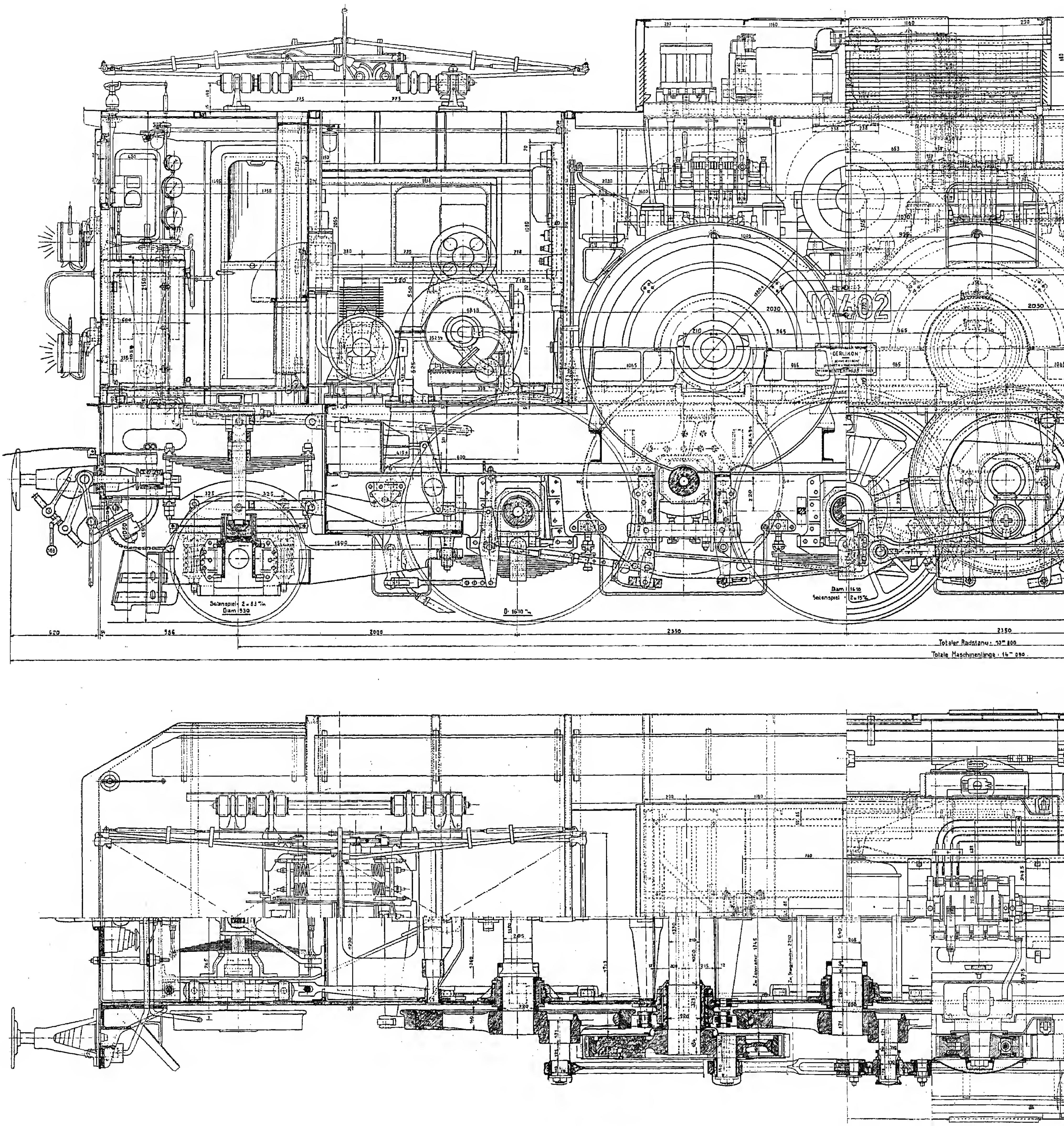
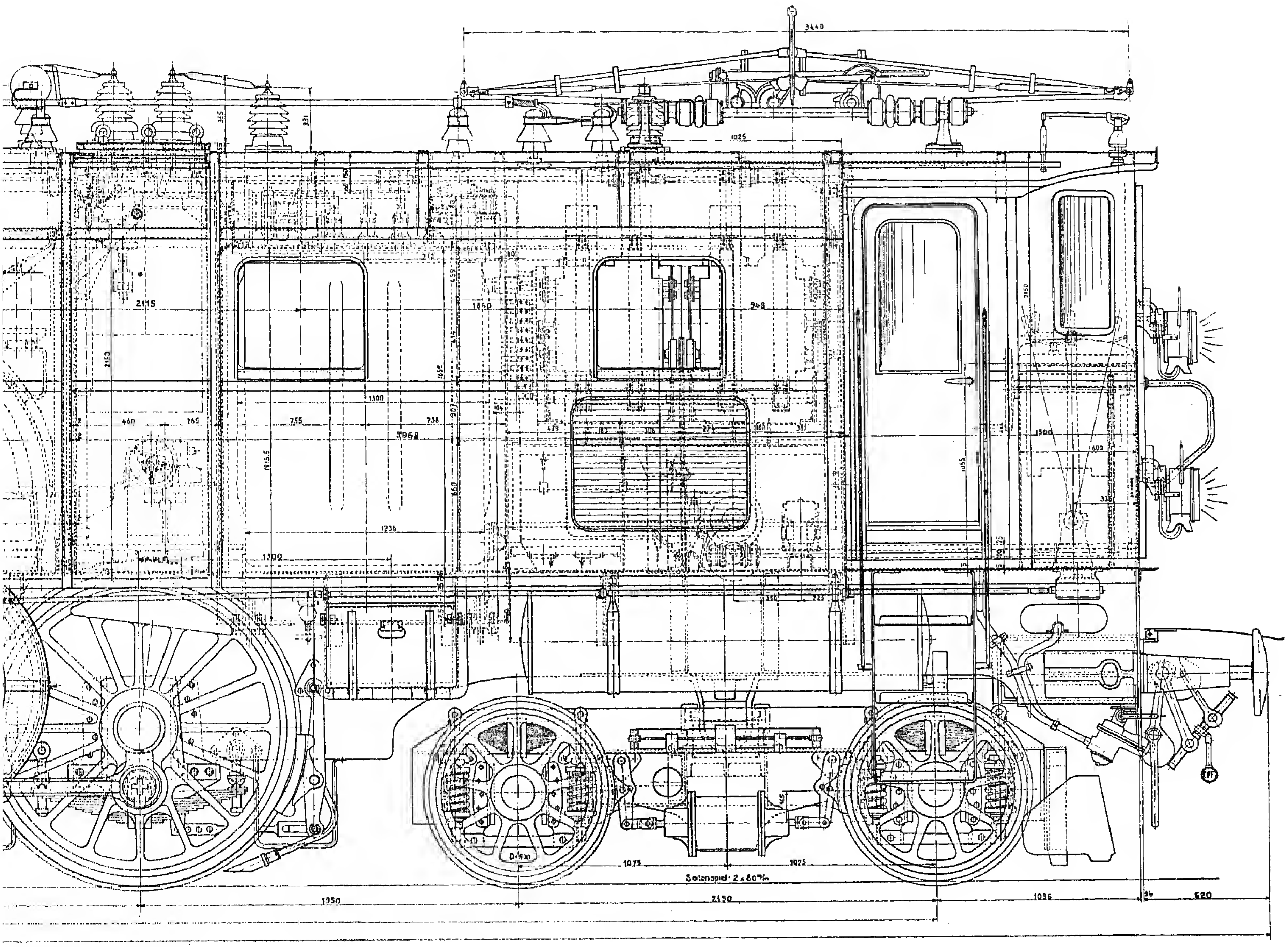
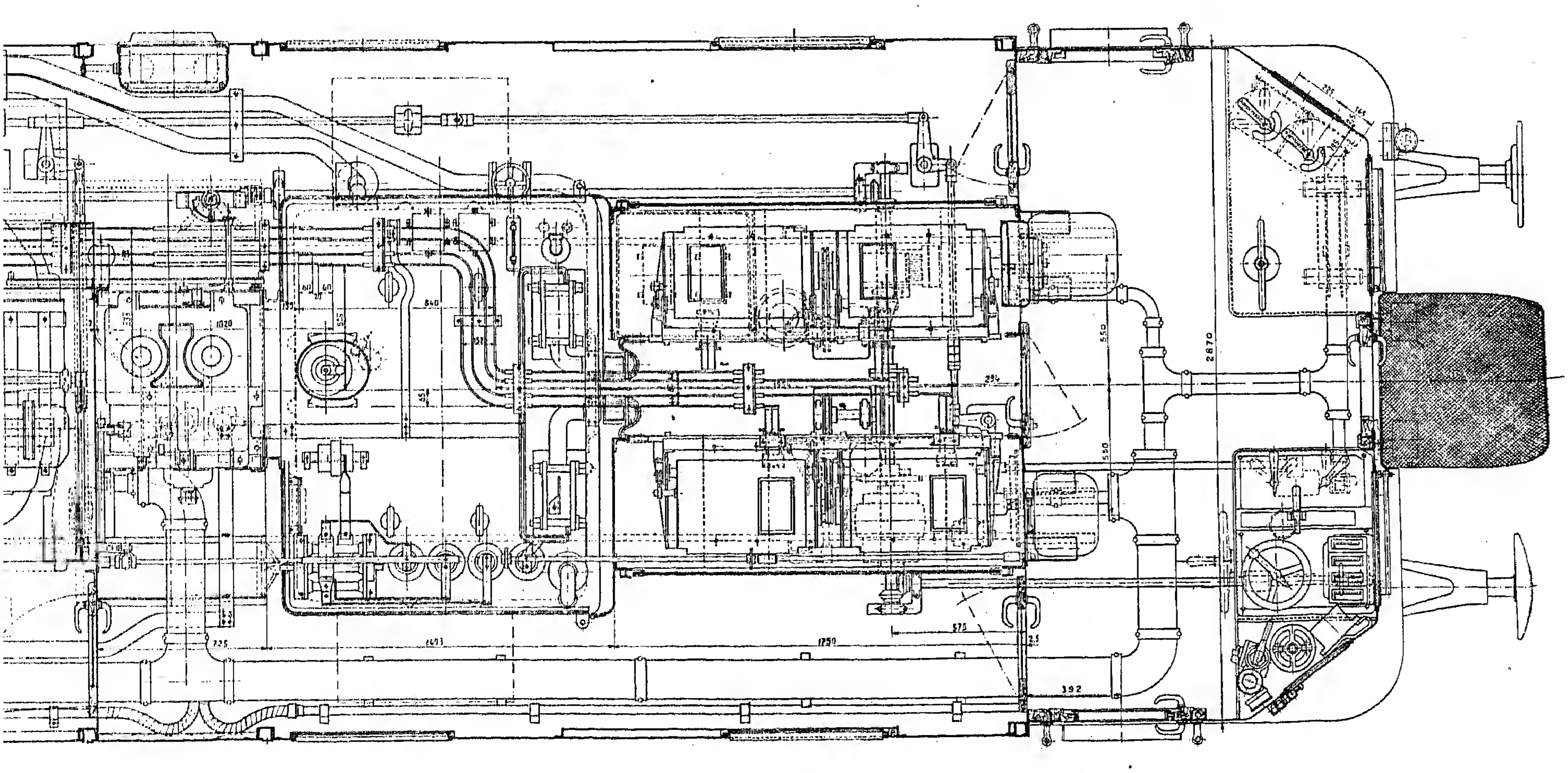


Abb. 2 und 3. Längsschnitt und Ansicht, Draufsicht und

(Nach einer Originalzeichnung der Schweizer. Lokomotiv-

: TEIL DER SCHWEIZER. LOKOMOTIVFABRIK WINTERTHUR





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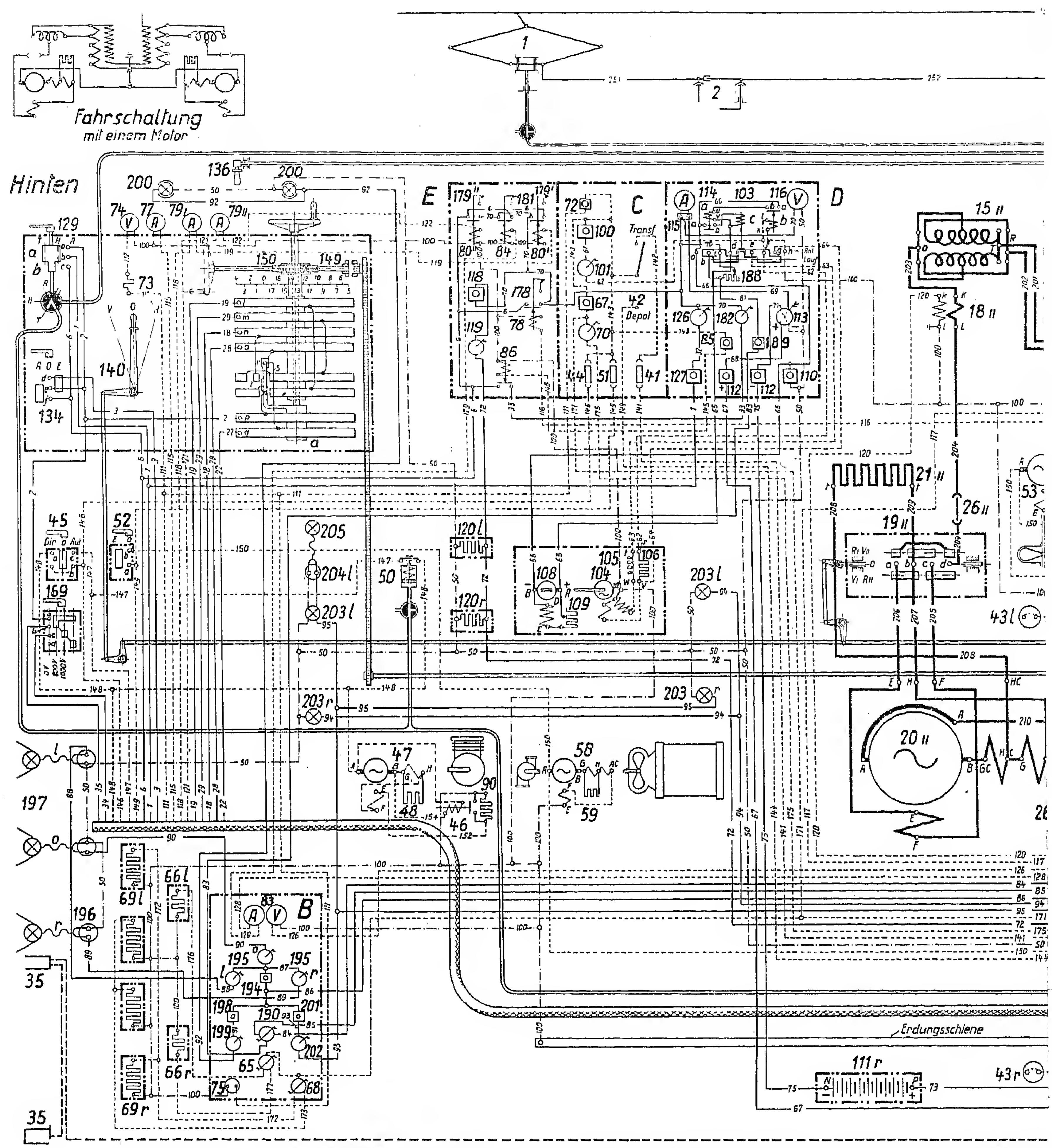
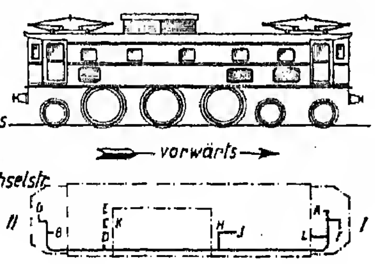
und Maschinenfabrik Winterthur.)



Hochspannungsstromkreis
Triebmotorenstromkreis
Zugsheizungsstromkreis
Wechselstr.-Hülfsbetr.stromkreis
Gleichstromkreis
Rückleitungen für Gleich- & Wechselstr.



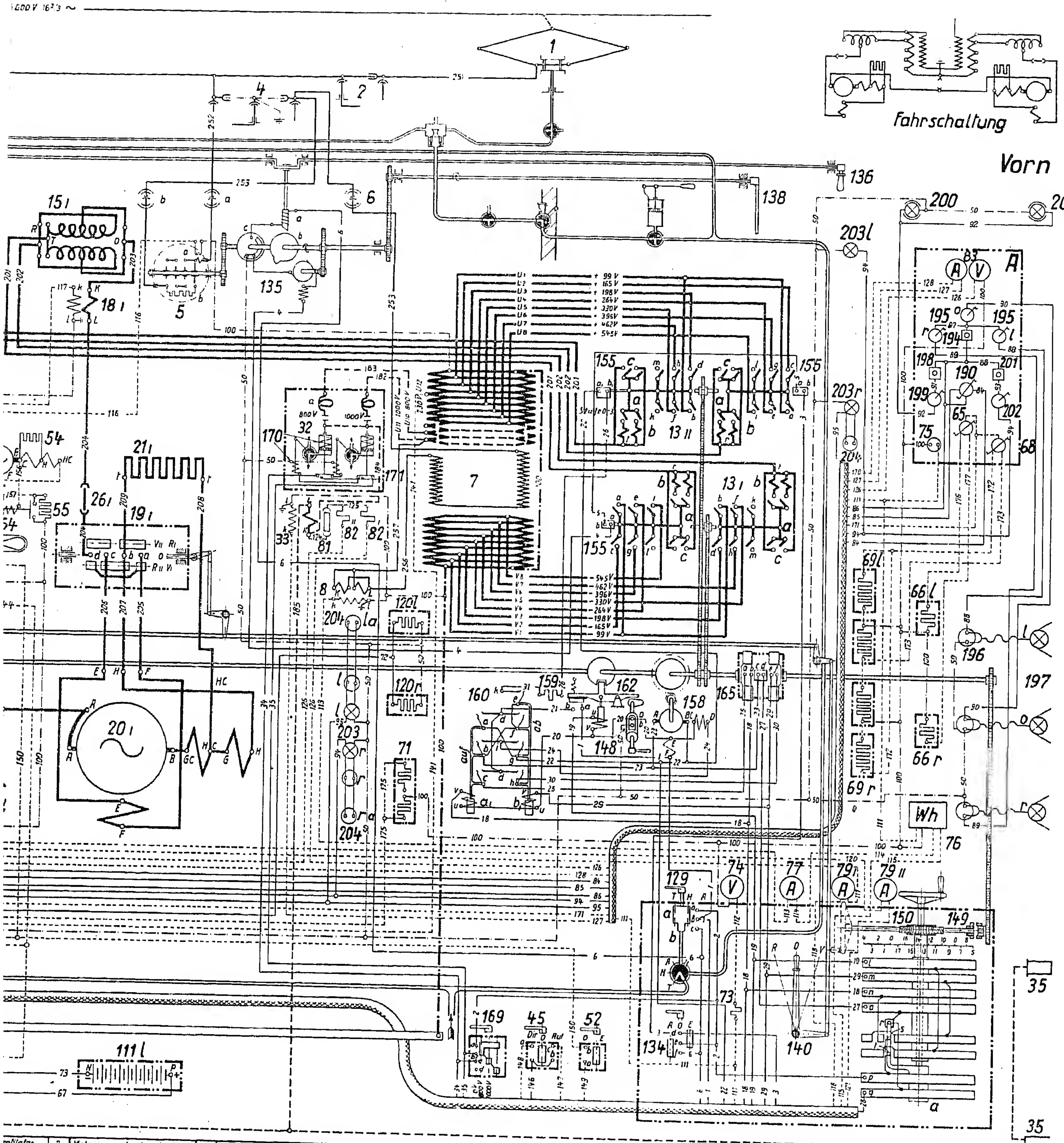
A	Norm. Schalttafel im Führerstand I
B	" " im Führerstand II
C	" " für Wechselstrom
D	Norm. Schalttafel für Gleichstrom
E	Schalttafel für Relais
F	Klemmenplatte im Führertisch I
G	" " im Führertisch II
H	" " im Hauptschalterraum
J	" " auf d. Transformer
K	" " über Hauptschlttafel
L	Klemmenplatte im Stufenschalterraum

A	Hauptstromkreise
1.	Hochspannungsstromkreis
1	Stromabnehmer
2	Trennmesser
3	———
4	Erdungsschalter
5	Hauptschalter
a	Stromwandler f. Max'stromrelais
b	Schutzwiderstand
6	Hochspannungseinführung
7	Stufentransformator
8	Stromwandler für Messinstr.
9-12	———
2.	Triebmotorenstromkreis
13	Stufenschalter
a	Funkenlöschschalter
b	Funkenlöschspule
14	———
15	Ueberschaltdrosselspule
16-17	———
18	Stromwandler für Triebmotor
19	Wendeschalter
20	Triebmotor
21	Ohm'scher Hulfspolshunt
22-25	———
26	Trennmesser
27-31	———

3.	Zugsheizungsstromkreis
32	Heizhüpfer
a	Funkenloschspule
33	Stromwandler für Zugsheizung
34	———
35	Heizkupplung
36-40	———
B	Nebenstromkreise
1.	Hülfsbetriebsstromkreis
41	Hptsich'g f. Hülfsbetr.str.kreise
42	Umschalter für Depotanschluss
43	Steckdose für Depotanschluss
44	Sicher'g fur Kompressormotor
45	Umsch. für Kompressormotor
46	Hüpfer fur Kompressormotor
47	Kompressormotor
48	Ohm'scher Hülfspolshunt
49	———
50	Kompressorautomat
51	Sicher'g d. Motors für Oelpumpe und Triebmotorventilator
52	Schalter z. Motor für Oelpumpe und Triebmotorventilator
53	Motor für Triebmotorventilator
54	Ohm'scher Hülfspolshunt
55	Ohm'scher Widerstand
56-57	———
58	Motor für Transf. Oelkuhlanlage
59	Ohm'scher Hülfspolshunt
60-63	———

64	Hüpfer für Trieb
65	Umschalter für F
66	Fusswärmeplat
67	Sicher'g für Führ und Oelwärmep
68	Umschalter f. Füh
69	Führerstandshei
70	Schalter für Oel
71	Oelwärmeplatte
72	Sicherung für
73	Vorschaltwiders für Fahrleitung
74	Voltmeter f. Fahr
75	Steckdose für S
76	Wattstundenzäh
77	Ampèremeter fü
78	Max'stromrelais
79	Ampèremeter fü
80	Max'stromrelais
81	Sicher'g z. Voltme
82	Vorschaltwidersta für Zugsheizu
83	Voltampèremete
84	Max'stromrelais
85	Sicher'g d. Nullsp für Haupts
86	Nullsp'gsrelais f
87-89	———
90	Ohm'scher Widerst
91-99	———

Abb. 10. Schaltungschema der Lokomotiven $A^{e\,8}/_{6}$



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motor

2.	Motorgeneratorstromkreis
100	Sicherg z. Motor d. Motorgener
101	Motorschalter d. Motorgenerat
102	———
103	Autom. Anlassapp. z. Motorgenerat
a	Gleichstromrelais
b	Wechselstromrelais
c	Umschaltspule
104	Motor des Motorgenerators
105	Induktiver Anlasswiderstand
106	Ohm'scher Vorschaltwiderstand
107	———
108	Generator d. Motorgenerators
109	Ohm'scher Widerstand
110	Sicherung des Generators
111	Batterie
112	Batteriesicherung
113	Batterieschalter
114	Ampèremeter für Batterie
115	Shunt zum Ampèremeter f. Batterie
116	Voltmeter für Batterie
117	———
118	Sicherung d. Oelbecherwärmer
119	Schalter f. Oelbecherwärmer
120	Oelbecherwärmer
121-125	———

3.	Steuerstromkreis
126	Schalter für Steuerstrom
127	Sicherung für Steuerstrom
128	———
129	Fernbetätigung f. Stromabnehmer
a	Verriegelungskont. f. Steuerstrom
b	Auslösekont. für Hauptschalter
130-133	———
134	Fernbetätigung für Hauptschalter
135	Steuermotor für Hauptschalter
a	Auslösespule für Hauptschalter
b	Sperrscheibe
c	Unterbrechungskontakt am Hauptsch.
136	Motorauslösung für Hauptschalter
137	———
138	Handantrieb für Hauptschalter
139	———
140	Fernbetätigung für Wendeschalter
141-147	———
148	Umschalter für Hand- bezw. elektr. Antrieb des Stufenschalters
149	Kupplung für Handsteuerung
150	Fernbetätigung d. Stufenschalters
a	Steuerkontr. des Stufenschalters
151-154	———
155	Verriegelkontakt am Stufenschalter
156-157	———
158	Stufenschaltermotor
159	Widerstand zum Stufenschltrmotor
160	Relais f. Stufenschaltermotor
a	Relais f. Aufschltg d. Stufenschltmot.
b	Relais f. Abschltg d. Stufenschltmot.
161	———
162	Sperrmagnet mit Einschaltkont.
163-164	———
165	Schaltwalze f. Antr. des Stufenschalt.
166-168	———
169	Fernschalter für Heizhüpfer
170	Elektro-pneumat. Antrieb d. Heizhüpf.
171	Verrieg. Kontakt der Heizhüpfer
172-177	———
178	Fallklappe z. Max.-relais für Hptstr.
179	Fallklappe z. Max.-relais f. Triebmot.
180	———
181	Fallklappe z. Max.-relais f. Zugsheiz.
182	Schalter f. Nullspgsrelais f. Hptschlt.
183-187	———

4.	Beleuchtungsstromkreis
188	Beleuchtungswiderstand
189	Sicherung für Beleuchtung
190	Umschalter für Beleuchtung
191-193	
194	Sicherung der Lok.-Laternen
195	Schalter f. Lokomotivlaternen
196	Steckdose für Lok.-Laternen
197	Lokomotivlaternen
198	Sicherung f. Führerstandlampe
199	Schalter für Führerstandlampe
200	Führerstandlampe
201	Sicherung für Innenlampen
202	Schalter für Innenlampen
203	Innenlampe
204	Steckdose für Handlampe
205	Handlampe

Verteilung der Leitungsnummern	
1 - 35	Steuerleitungen
61 - 75	Motorgenerator Batterie
81 - 95	Beleuchtungsleitungen
111 - 129	Messleitungen
141 - 156	Depotanschluss - Kompr.-Ventilat. Oelkühlermotor
171 - 177	Führerstandsheizung, Oelwärmepl.
181 - 185	Zugsheizung
201 - 210	Triebmotoren
251 - 257	Hochspannung

Cliché der Maschinenfabrik Oerlikon.

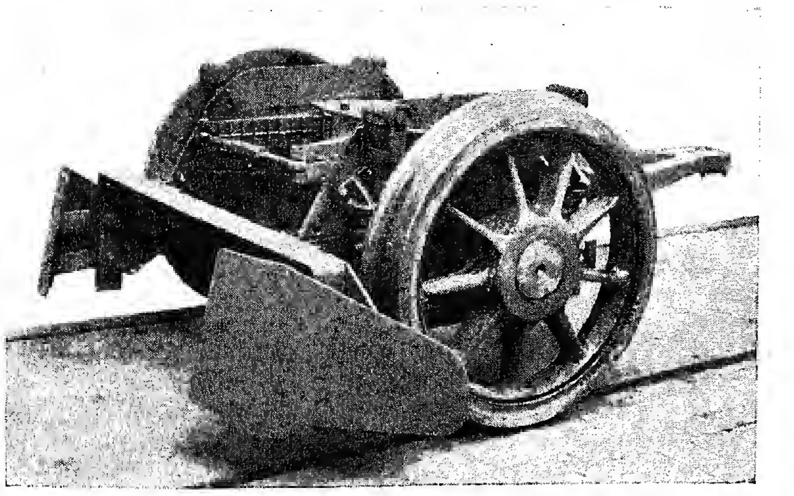


Abb. 7. Einachsiges Bisselgestell.

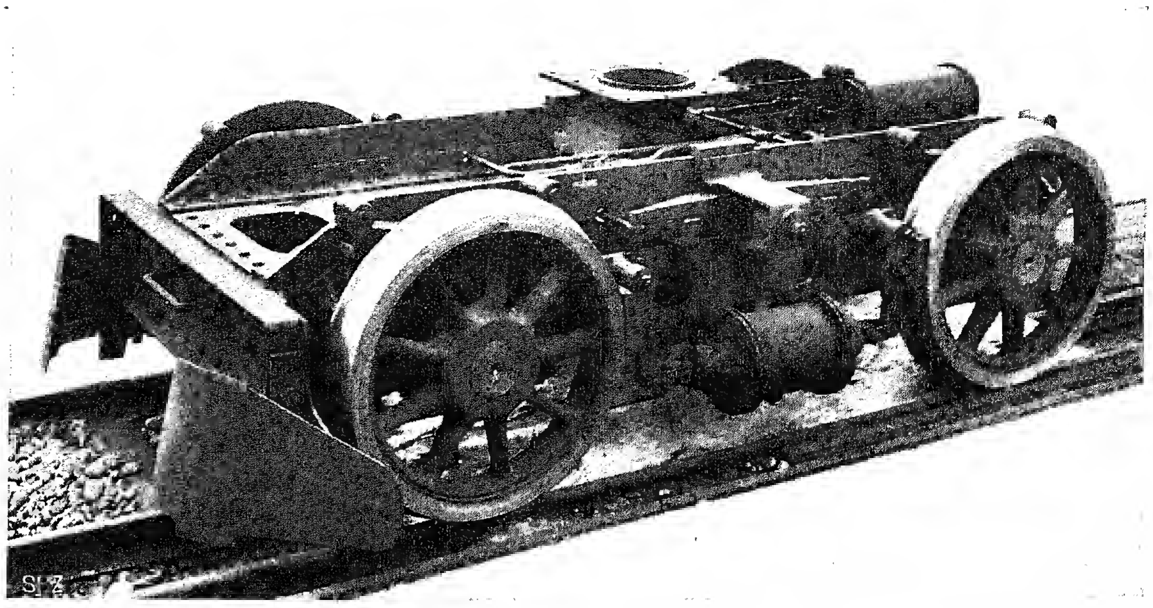


Abb. 6. Zweiachsiges Laufräder-Drehgestell.

Gestänge verbunden, das aus zwei Winkelhebeln und einer, unter der zwischen diesen Achsen gelagerten Vorgelegewelle durchführenden Zugstange gebildet wird. Die Federaufhängung der dem Bissel benachbarten Triebachse ist durch Einschaltung von zwei Längsbalanciers und eines Querbalanciers mit der gefederten Abstützung des Hauptrahmens auf das Bisselgestell zu einem System verbunden. Der Querbalancier überträgt die Last auf eine mit Hülfe von Lenkern gehaltene Zentralstütze, die am untern Ende auf der Kugelpfanne des Bisselgestelles aufsitzt.

Die Abstützung der Lokomotive auf ihren Achsen erfolgt also in vier Punkten, von denen die äussern beiden im Maschinenlängsmittel über dem zweiachsigen Drehgestell und der hintern kombinierten Triebachs-Bisselachs-Radgruppe liegen, während die beiden andern Stützpunkte in den Lager-Ebenen der beiden dem Laufachsgestell benachbarten Triebachsen sich befinden und für die nötige Seitenstabilität des Fahrzeuges sorgen. Diese Unterteilung des Federgehänges hat sich in jeder Beziehung bewährt.

Antriebmechanismus. Der Antrieb der drei Triebachsen ist dem der 1-C-1 ($B^{e\,3}/_6$) Probelokomotive Nr. 11201 der Schweizerischen Bundesbahnen nachgebildet, mit welchem Lokomotivtyp seit seiner Inbetriebsetzung anfangs 1919 nur gute Erfahrungen gemacht worden sind. Zwei in der Lokomotive hochgelagerte, sowohl mit dem Rahmen als auch unter sich solid verbundene Gestellmotoren treiben mit Hülfe von beidseitigen Zahnrädern je eine jedem dieser Motoren zugeordnete Vorgelegewelle an, die zugleich als Kurbelachse dient. In die Zahnkolben (Abb. 8) ist eine weiche Federung eingebaut. Die Verzahnung ist schraubenförmig ausgebildet, derart, dass für die (je 150 mm breiten) Zahnräder der beiden Seiten zusammengenommen sich eine Pfeilverzahnung ergibt. Von den beiden Vorgelegewellen aus wird die Antriebkraft der Motoren auf die drei Triebachsen mit Hülfe von Dreieckstangen und an diese angelenkten Kuppelstangen übertragen.

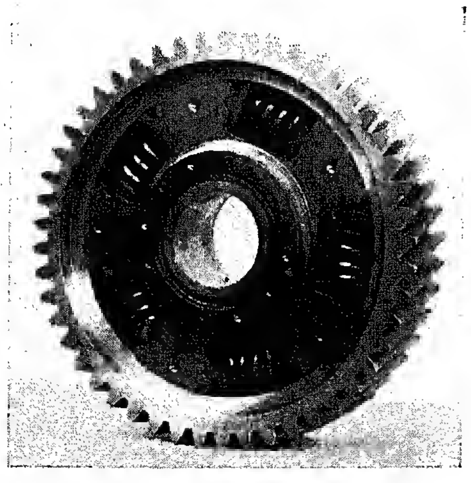


Abb. 8. Gefederter Zahnkolben der Triebmotoren.

Rahmenbau. Der Hauptrahmen der Lokomotive besteht aus zwei 25 mm starken Längsblechen, deren zahlreiche Querversteifungen aus der Zusammenstellungszeichnung (s. Tafel) zu ersehen sind. Besonders hervorgehoben sei die Ausbildung des Rahmens in dem unterhalb der Motoren gelegenen Teil: Längsträger aus Stahlguss, auf jeder Seite mit dem Rahmenblech fest verschraubt, bilden das Fundament, auf das sich die Füsse der beiden Motoren abstützen. In diese Längsträger ist bei jedem Motor unterhalb des Motorlagers ein Sattel eingebaut, dessen obere, konzentrisch mit der Motorwelle ausgedrehte Sitzfläche dazu dient, den Motorlagerhals aufzunehmen und so beim Einbau den Motor ohne weiteres an seinen in Bezug auf guten Zahneingriff richtigen Ort zu bringen. Mit den erwähnten Längsträgern unter den Motorfüssen sind überdies bei jeder Vorgelegewelle die Stahlguss-Lagerscheren zusammengeschraubt, die zur Aufnahme der Vorgelegewellen-Lager dienen; der mittlere Rahmenteil unterhalb der Motoren bildet so ein kräftiges Ganzes, das unzulässige Deformationen des Rahmens verhindert. Der Rahmenausschnitt unterhalb jedes Vorgelegewellen-Lagers wird durch eine starke geschmiedete Zange überbrückt.

Bremsen. Sämtliche Triebräder sind doppelseitig abgebremst. Im fernern wirkt je ein Bremsklotz auf die Räder des zweiachsigen Laufachsgestelles (Abbildung 6), während das Bisselgestell ohne Bremse ist. Betätigt wird die Bremse mit Hülfe der doppelten Westinghouse-Bremse (automatische Bremse und Regulierbremse) mit der etwa 90 % des Adhäsionsgewichtes, sowie 60 % des auf dem Laufachsgestell lastenden Gewichtes abgebremst werden kann. Die Triebradbremsen können auch von den Führerständen aus von Hand angezogen werden.

Luftleitungsanlage. Zwei Behälter von je 400 l Inhalt dienen zur Aufspeicherung der vom Motorkompressor gelieferten Druckluft. Einer dieser Behälter ist für die Bremse bestimmt, der andere dient zur Speisung der pneumatischen Apparate der Lokomotive; doch ist die Verbindung der Behälter unter sich derart, dass bei Druckabnahme im Brems-Luftbehälter stets Luft vom Apparaten-Luftbehälter nachströmen kann, während der umgekehrte Vorgang durch ein Rückschlagventil verhindert wird.

Der Lokomotivkasten. Der auf die ganze Länge des Rahmens aufgebaute Lokomotivkasten enthält die übliche Unterteilung in einen mittlern Maschinenraum und je zwei an den Enden befindliche Führerstände. Eine weitere Unterteilung im Innern des Maschinenraumes (Abbildung 9) ist mit Rücksicht auf die Ventilation der Motoren geschaffen worden. Wir werden darauf zurückkommen.

II. Elektrische Ausrüstung.

Das Bestreben der Schweizerischen Bundesbahnen, die Lagerhaltung kompletter Maschinen, Apparate und deren Bestandteile zu vereinfachen, um damit anderseits die Anschaffungs- und Unterhaltungskosten der Fahrzeuge möglichst herabzusetzen, hat seit einer Reihe von Jahren zur schrittweisen Normalisierung einer grösseren Anzahl gründlich erprobter und bewährter Ausrüstungsteile geführt. Aus dem vor kurzem hier erschienenen bezüglichen Artikel von Ingenieur F. Steiner (Bd. 85, S. 83 und 103, 14./21. Feb. 1925) ist den Lesern der „S. B. Z." bekannt, wie weit diese Normalisierung durchgeführt worden ist. Die normalisierten Apparate sind zum Teil in jenem Artikel dargestellt. Wir können uns also hier auf die Teile der elektrischen Ausrüstung beschränken, die nicht unter die Normalisierung fallen, oder die gegenüber frühern Konstruk-

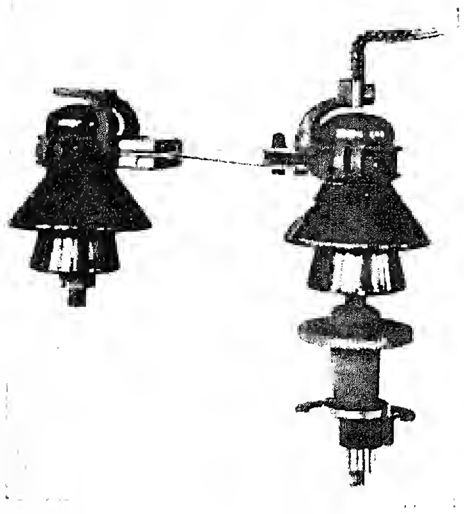


Abb. 11. Hochspannungs-Trennmesser.

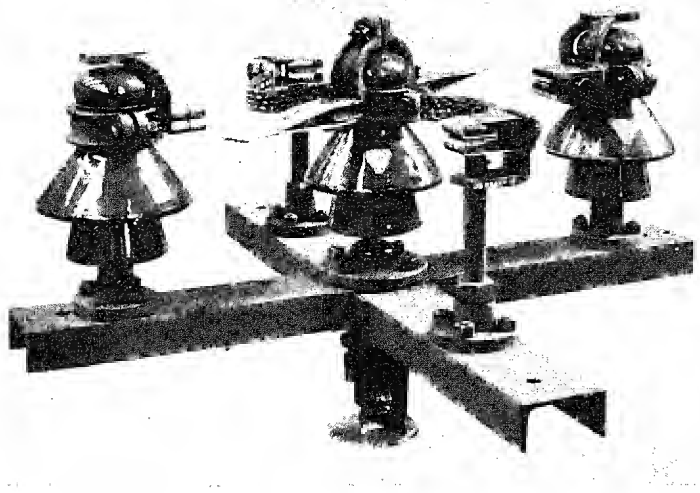


Abb. 13. Erdungs-Schalter zum Hauptschalter.

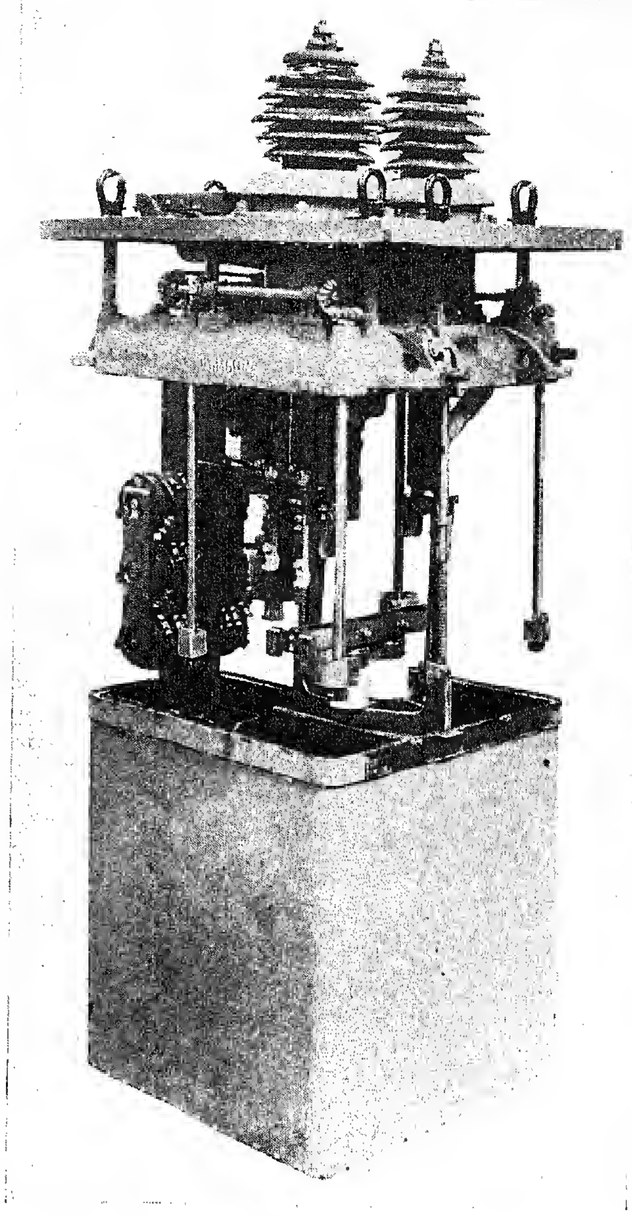


Abb. 12. Hauptschalter.

tionen wesentlich Neues bieten. Im übrigen verweisen wir auf das Schaltungschema (Abb. 10), dessen Legende eine Aufstellung aller vorhandenen Apparate gibt.

Die Anordnung der elektrischen Ausrüstung im Innern des Lokomotiv-Kastens (vergl. Abbildung 2/3, Tafel, und 4) ist durch die zentrale Lagerung der Motoren bestimmt. Nach vorn, gegen das zweiachsige Laufachsgestell hin, schliessen an den Motorraum der Hauptschalter und die Zugheizungs-Hüpfer, dann der Stufentransformator und schliesslich die zwei längsgestellten Stufenschalter. Der Raum zwischen diesen Stufenschaltern, der zum Revidieren derselben dient, kann vom vordern Führerstand aus durch eine verriegelte Türe begangen werden. Gegen den hintern Führerstand zu schliessen an den Triebmotorenraum die Transformatorkühlgruppe mit aufgebautem Motorgenerator und die Kompressorgruppe an. In diesem Raume sind ferner die Gleichstrom-, Wechselstrom- und Relais-Schalttafeln untergebracht (vergl. die Skizze links unten auf dem Schaltungschema Abb. 10, Tafel). Im fernern befinden sich in der Nähe des Kompressors an der betreffenden Führerstand-Rückwand der Kompressor-Automat, der Anlasshüpfer und der Widerstand zum Kompressormotor. Im Dachaufsatz über dem Motorraum, mit dem betreffenden Dachteil durch ein Gerüst verbunden und als Ganzes ein- und ausbaufähig, sind die Ueberschalt-Drosselspulen, die Ohm'schen Hülfspolshunts der Triebmotoren und bei der mit elektrischer Rekuperations-Bremseinrichtung versehenen Lokomotive Nr. 10401 noch die Bremsdrosselspule untergebracht.

Die Abnahme des hochgespannten Stromes (im folgenden Hauptstrom genannt) aus der Fahrleitung erfolgt durch zwei kräftig versteifte, in üblicher Weise durch Druckluft betätigte *Scheren-Stromabnehmer.* Die beiden äussersten Lagen der Wippen-Schleifflächen betragen 4,495 m, bezw. 7,195 m über S. O. K. bei vollständig gesenkten, bezw. bei ganz hochgestellten Stromabnehmern, d. h. die Stromabnehmer beherrschen eine Höhendifferenz von 2,7 m. Der aus Stahlrohren hergestellte bewegliche Teil der Stromabnehmer ist durch einen automatisch wirkenden, von Witterungs- und Temperatureinflüssen unabhängigen *Luftdrosselungshahn* gegen ein allzu rasches Herunterfallen gesichert, sodass das Scherengestell beim Herunterlassen aus jeder beliebigen Höhenlage ruhig und ohne merkbaren Stoss seine unterste, bezw. die Ruhelage einnimmt. Um beim Senken ein rasches Entweichen der Druckluft aus den Zuleitungen und damit eine kürzere Senkzeit zu ermöglichen, ist in die Verbindungszuleitung der Stromabnehmer ein selbsttätiges *Ausströmventil* eingebaut worden, durch das die Druckluft ins Freie entweichen kann, ohne erst das ganze Leitungssystem einschliesslich Betätigungsventile der Führerstände durchfliessen zu müssen. Beiden Stromabnehmern ist je ein *Hochspannungstrennmesser* (Abbildung 11) und je ein *Entleerungshahn* zugeordnet, mittels deren die Stromabnehmer bei Bedarf elektrisch, bezw. pneumatisch ausser Tätigkeit gesetzt werden können. Die Betätigung der Stromabnehmer-Trennmesser kann nur mittels eines Handgriffes vorgenommen werden, der mit der Stromabnehmer-Luftzuleitung derart verriegelt ist, dass er erst nach Oeffnung eines in diese eingebauten, mit Signalpfeife versehenen Entleerungshahns abgehoben werden kann.

Als *Hauptschalter* gelangte bei den ersten dreizehn Lokomotiven noch der ältere Schaltertyp mit einfacher Unterbrechung und pneumatischer Einschaltvorrichtung zur Verwendung (Abb. 12), während die weitern mit dem normalisierten Schalter mit Vielfachunterbrechung und elektromotorischer Einschaltung (siehe „S. B. Z.", Bd. 85, S. 107, 21. Febr. 1925) ausgerüstet sind. Bei den neuern Lokomotiven ist ausser der sowieso vorhandenen Handbetätigung am Schalter selbst noch ein besonderer Handantrieb (Pos. 138 in Schema) vorhanden, der die Einschaltung des Hauptschalters vom Führstand I aus mittels Hebel gestattet. Beide Schaltertypen besitzen Vorkontakte, womit beim Einschalten erst die sogenannten Stoss- oder Dämpfungs-

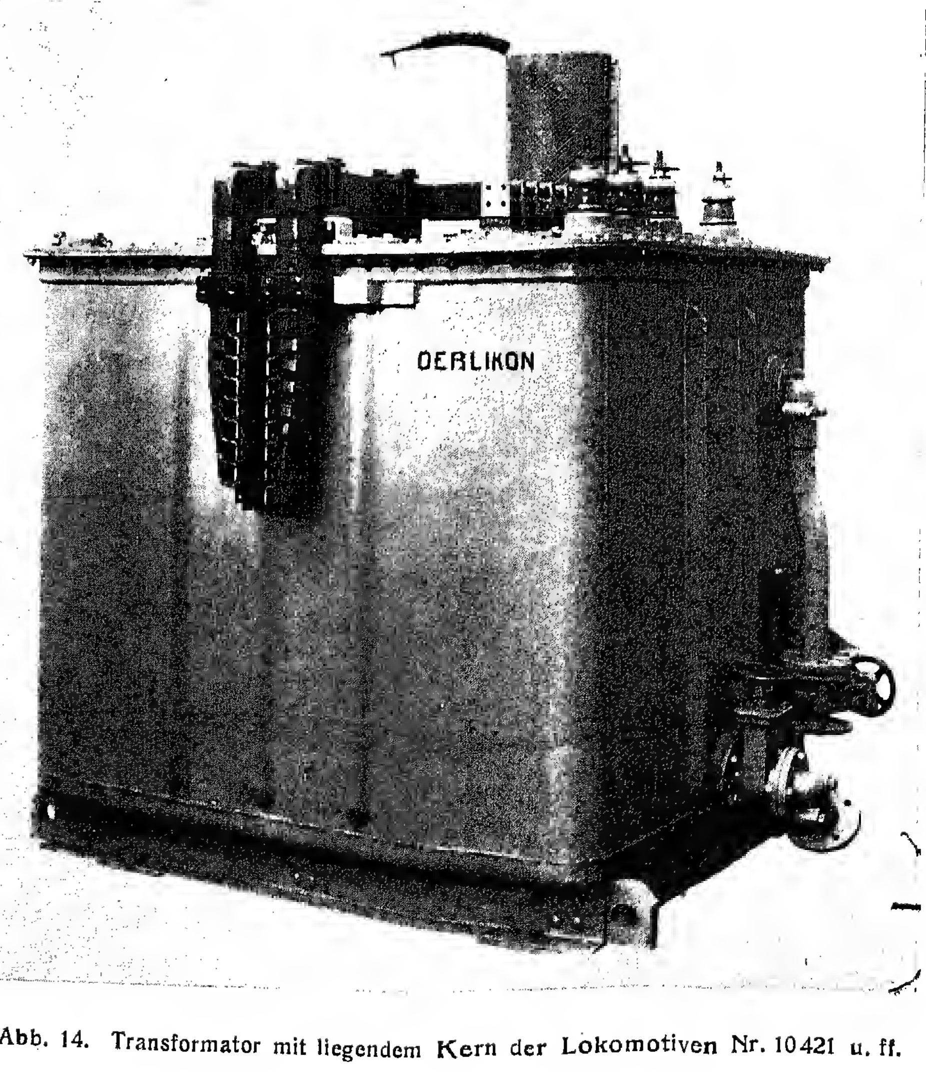


Abb. 14. Transformator mit liegendem Kern der Lokomotiven Nr. 10421 u. ff.

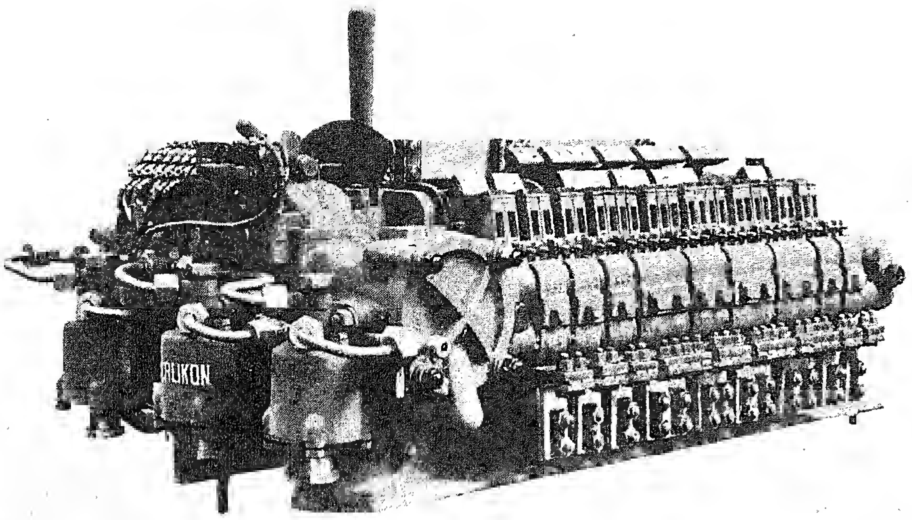


Abb. 17. Wendeschalter mit elektro-pneumatischem Antrieb.

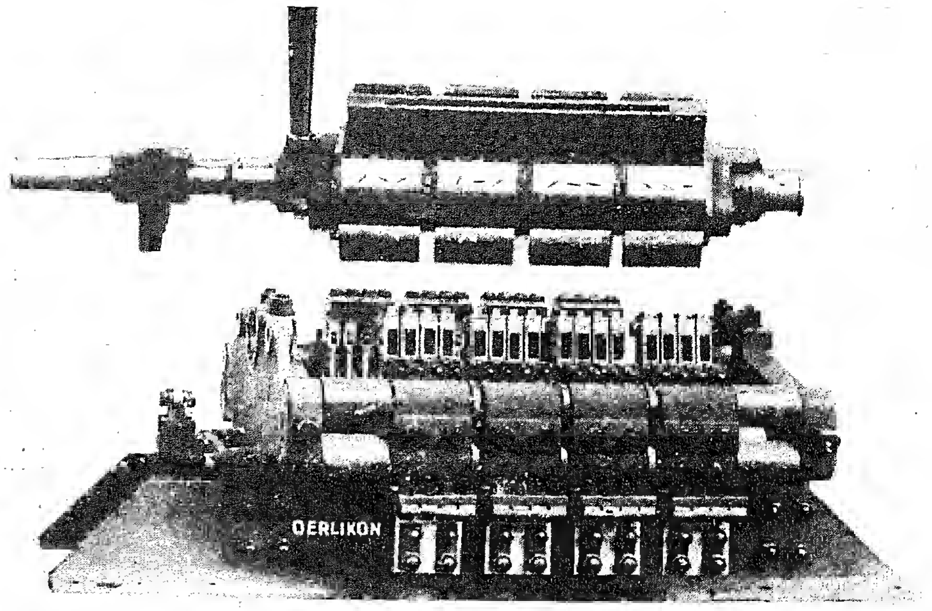


Abb. 18. Wendeschalter mit Handantrieb.

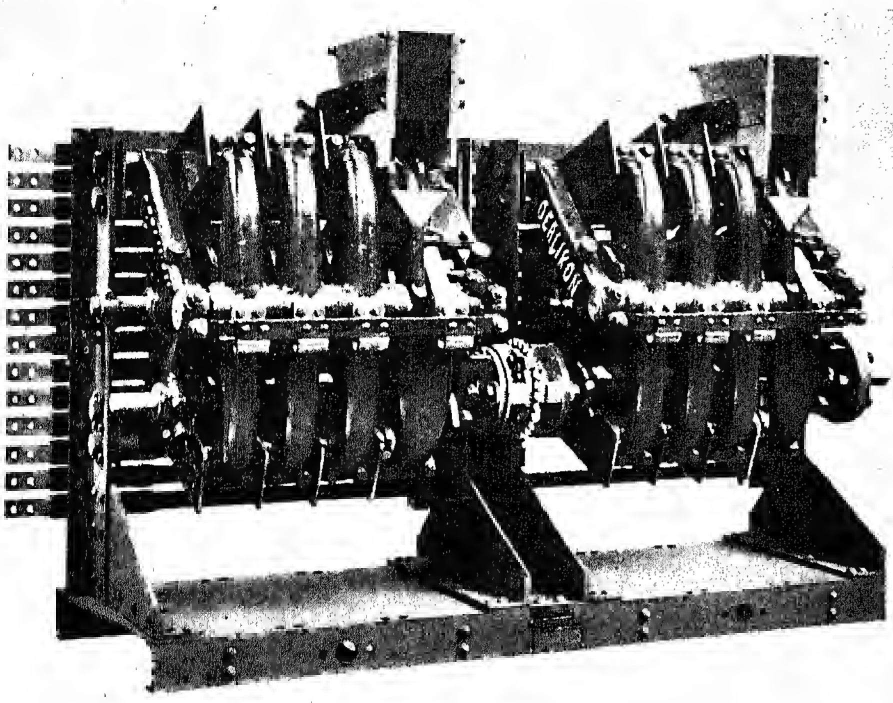


Abb. 16. Stufenschalter für elektrische oder Handsteuerung.

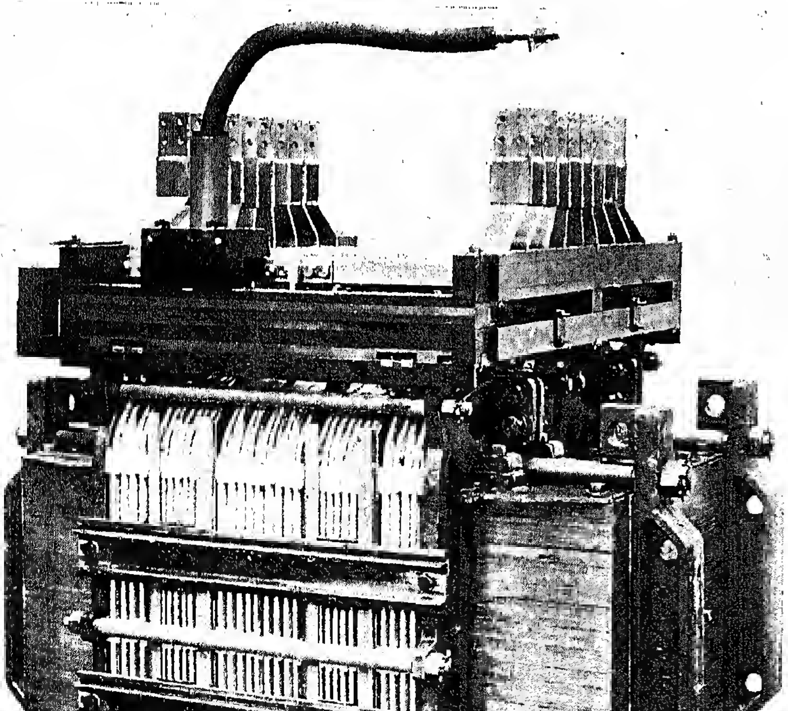


Abb. 15. Transformator mit liegendem Kern der Lokomotiven Nr. 10421 u. ff.

widerstände vorgeschaltet werden, bevor die Hauptkontakte auflaufen. Die Hauptschalterzelle und die Oelkübelablassvorrichtung des Hauptschalters sind mit einem *Erdungsschalter* (Abbildung 13) und dem weiter oben erwähnten Verriegelungshandgriff derart verbunden, dass sie erst nach Oeffnung des Entleerungshahns und Senkung der Stromabnehmer, sowie Erdung der Zuführungsleitungen zugänglich werden. Der Erdungsschalter ist zweipolig und verbindet in geschlossenem Zustande beide Schalterpole mit Erde, damit die Revision der Maschine auch bei allallfällig herabhängenden Fahrdrahtteilen gefahrlos vor sich gehen kann.

Für die elektrische Auslösung des Hauptschalters dient ein in dessen Innern angeordneter Stromwandler, der auf das Hauptstromrelais (Pos. 78 im Schema) wirkt. Diese Anordnung des Stromwandlers hat sich auf Grund der bisher gemachten Erfahrungen als die zuverlässigste erwiesen, indem Kurzschlüsse und Ueberströme, die infolge von Defekten oder Ueberlastungen im Innern des Transformators oder auch im Hauptschalter selbst auftreten, unter allen Umständen auf die Auslösestromkreise des Hauptschalters wirken, während dies bei den früher üblichen Anordnungen, mit besondern, nach der Oberspannnungs-Wicklung des Stufentransformators eingebauten Stromwandlern, nicht der Fall war.

Die *Stufentransformatoren* sind als Kerntyp gebaut, und zwar für die Lokomotiven Nr. 10401 bis 20 mit aufrecht stehendem Kern und konzentrischer Spulenanordnung (Abbildung 14), für die folgenden Lokomotiven mit liegendem Kern und Scheibenwicklung (Abbildung 15). Die erste dieser Ausführungsarten hat getrennte Ober- und Unterspannungswicklungen, während die letzte als Autotransformator geschaltet ist. Die Verschiedenheit in der Ausführung der Transformatoren ist begründet in dem Bestreben, die thermisch reichlich bemessenen Triebmotoren bei entsprechender Erhöhung der Lokomotiv-Leistung voll ausnützen zu können unter gleichzeitiger Verminderung des Transformator- und Lokomotiv-Gewichtes. Sämtliche Transformatoren besitzen rechteckige Spulen, sowie glatte Oelkessel (Abbildung 14) mit Oelumlaufkühlung durch besondere, kompendiös angeordnete Oelkühlergruppen (vgl. Abbildung 22). Die Niederspannungs-Wicklungen bilden unter sich zwei, nach der bekannten sogen. Plus-Minus-Schaltung in Serie geschaltete Gruppen mit gleichen absoluten Spannungs-Stufen. Die den Triebmotoren zugeführte Spannung beträgt maximal 536 Volt. Ferner besitzt die Niederspannungs-Wicklung Anzapfungen für 800 und 1000 Volt zum Anschluss der Zugsheizung.

Alle Transformatoren sind ausgerüstet mit einer, durch das Lokomotivdach ins Freie führenden Gasabzugsvorrichtung, bestehend aus einem Rohrbogen, der einerseits mit dem Transformatorendeckel fest verschraubt und anderseits

mit einem gewellten flexiblen Stahl- oder Tombakschlauch verbunden ist. Dieser ist an das im Lokomotivdach eingesetzte, mit Schutzkappe versehene Abzugsrohr angeschlossen und gleicht somit die zwischen Lokomotivdach und Transformator vorkommenden relativen Verschiebungen aus. Zwischen Schutzkappe und Abzugsrohr ist zur Verhinderung des Eindringens von Fremdkörpern ein Sieb angebracht. Ferner vermittelt ein an den Rohrbogen angeschlossenes, unter den Lokomotivboden führendes Rohr den Ablauf von allfällig sich bildendem Kondenswasser.

Diese Einrichtung dient zur Verhinderung des Eindringens von Oelgasen in das Lokomotiv-Innere, die sich unter gewissen Umständen infolge von Windungsschluss im Transformator entwickeln und, wie von einem bestimmten Fall her noch erinnerlich, bei gewissem Mischungsverhältnis mit der umgebenden Luft an den Schaltfunken der verschiedenen Apparate sich entzünden und zu Zerstörungen führen können. Aus den gleichen Gründen werden die in den Stufenschalterraum führenden Niederspannungs-Leitungsbündel sowie die Anschlusstellen am Transformator sehr sorgfältig gasdicht abgeschlossen.

Die *Stufenschalter,* von denen auf jeder Lokomotive zwei vorhanden sind, stellen, wie Abbildung 16 erkennen lässt, ein sehr kompendiös gebautes System von mittels Nockenscheiben betätigten Schalthebeln mit zentraler Funkenlöschung dar. Sie bestehen je aus zwei, mittels Isolierkupplungen mechanisch verbundenen und elektrisch getrennten Hälften, von denen jede dem entsprechenden Schenkel einer der beiden *Ueberschalt-Drosselspulen* (Pos. 15 im Schaltungschema) zugeordnet ist. Mit Rücksicht auf die gewünschte Auswechselbarkeit mit den Stufenschaltern der früher gelieferten C^{e} $^{6}/_{8}$ (1 C-C 1) Lokomotiven wurden die Stufenschalter zwölfstufig vorgesehen, trotzdem hier nur je neun Stufen ausgenützt sind. Jede Stufenschalterhälfte weist drei Doppel-Stufenhebel und einen mit Funkenlösch-Kontakthebel verbundenen Hauptkontakthebel auf.

Die beiden Stufenschalter jeder Lokomotive werden elektromotorisch oder von Hand, und zwar in bekannter Weise in Wechselschaltung gesteuert, d. h. es arbeitet abwechslungsweise nur je der eine oder andere, wodurch der Kraftaufwand für die Betätigung auf ein Minimum herabgesetzt werden konnte, was insbesondere bei Handsteuerung äusserst günstig zur Auswirkung kommt.

Die *Wendeschalter* der mit Nutzbremsung ausgerüsteten Lokomotive Nr. 10401 (Abbildung 17) werden elektro-pneumatisch gesteuert, während die aller folgenden Lokomotiven mittels Gestänge nur von Hand bedient werden (Abbildung 18).

Die *Triebmotoren* (Abbildung 19) sind, wie bei allen bisher von der Maschinenfabrik Oerlikon gelieferten Einphasenstrom-Lokomotiven, als kompensierte Serie-Motoren mit phasenverschobenen Hülfsfeldern ausgeführt. Sie haben 950 mm Kollektor-Durchmesser, sind mit einer 16-poligen Wicklung versehen, und wiegen je 10550 kg mit Zahnkolben. Sie leisten einstündig je 1100 PS am Triebrad-Umfang bei 400 Volt Klemmenspannung. Ihre charakteristischen Daten gehen aus Abb. 20, ihre Schaltungsweise aus den kleinen Schaltschemata oben auf Abb. 10 (Tafel) hervor. Ihre Umsteuerung beim Fahrtrichtungswechsel erfolgt durch Umkehrung der Stromrichtung in der Erregerwicklung.

Als konstruktive Neuerung bei den Triebmotoren soll die Anordnung der Haupt- und Hülfsfeld-Wicklungen hervorgehoben werden, die als fertig gewickelte Polspulen gebaut und unter Verwendung besonderer, als Kühlkanäle ausgebildeter Keile in den Statoreisenkörper eingelegt und befestigt sind. Besondere Sorgfalt wurde ausserdem auf die Durchbildung einer günstigen und wirksamen Kühlluft-Führung im Stator und im Rotor gelegt. Die beiden Triebmotoren werden künstlich gekühlt mittels einer auf sie aufgebauten gemeinsamen Ventilatorgruppe (Abb. 21). Die Kühlluft tritt durch Jalousien in den Seitenwänden ins Innere des Lokomotivkastens ein, wird durch den Ventilator angesaugt, durch die Motoren gedrückt und auf deren Kollektorseite in den separat verschalten Raum ausgeblasen. Ueber diesem Raum und zugleich über den Motoren befindet sich ein Dachaufsatz, durch dessen Jalousien die Kühlluft wieder ins Freie gelangen kann.

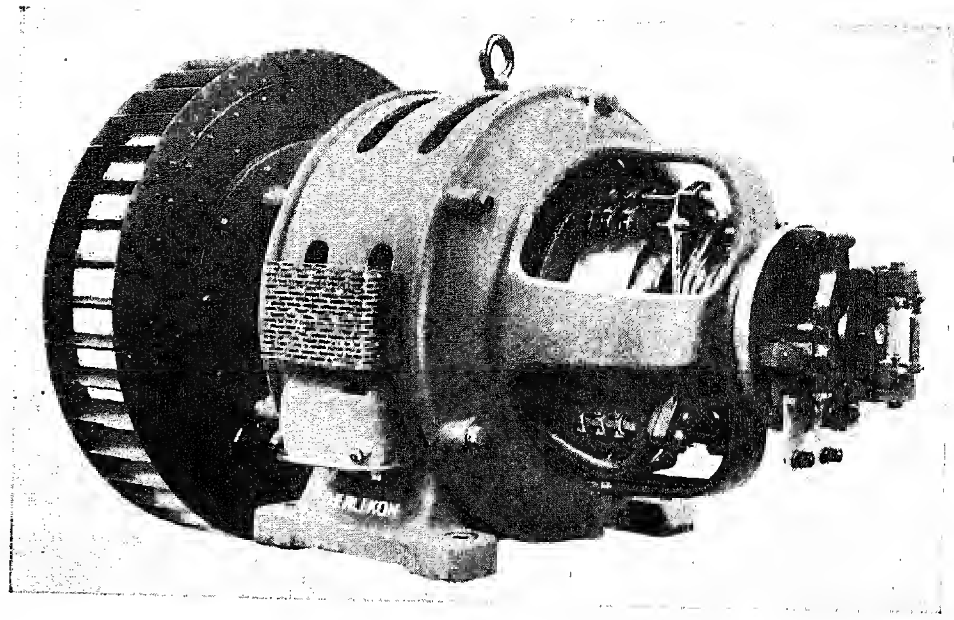


Abb. 21. Ventilatorgruppe der Triebmotoren.

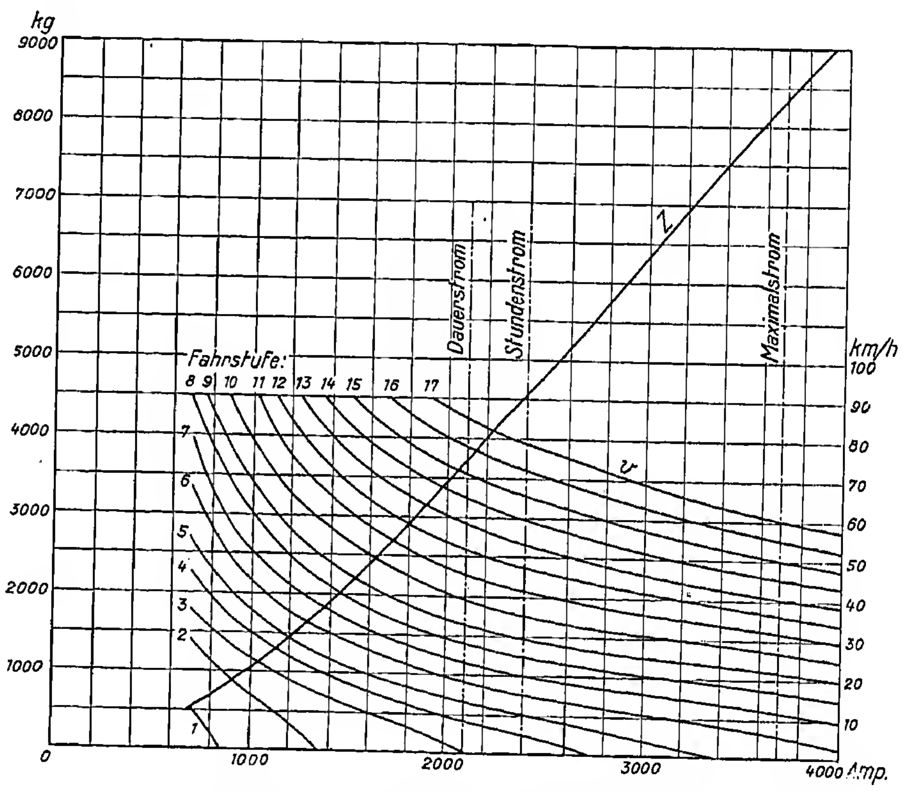


Abb. 20. Zugkraft Z und Fahrgeschwindigkeit v der Lokomotive in Funktion des Motorstroms.

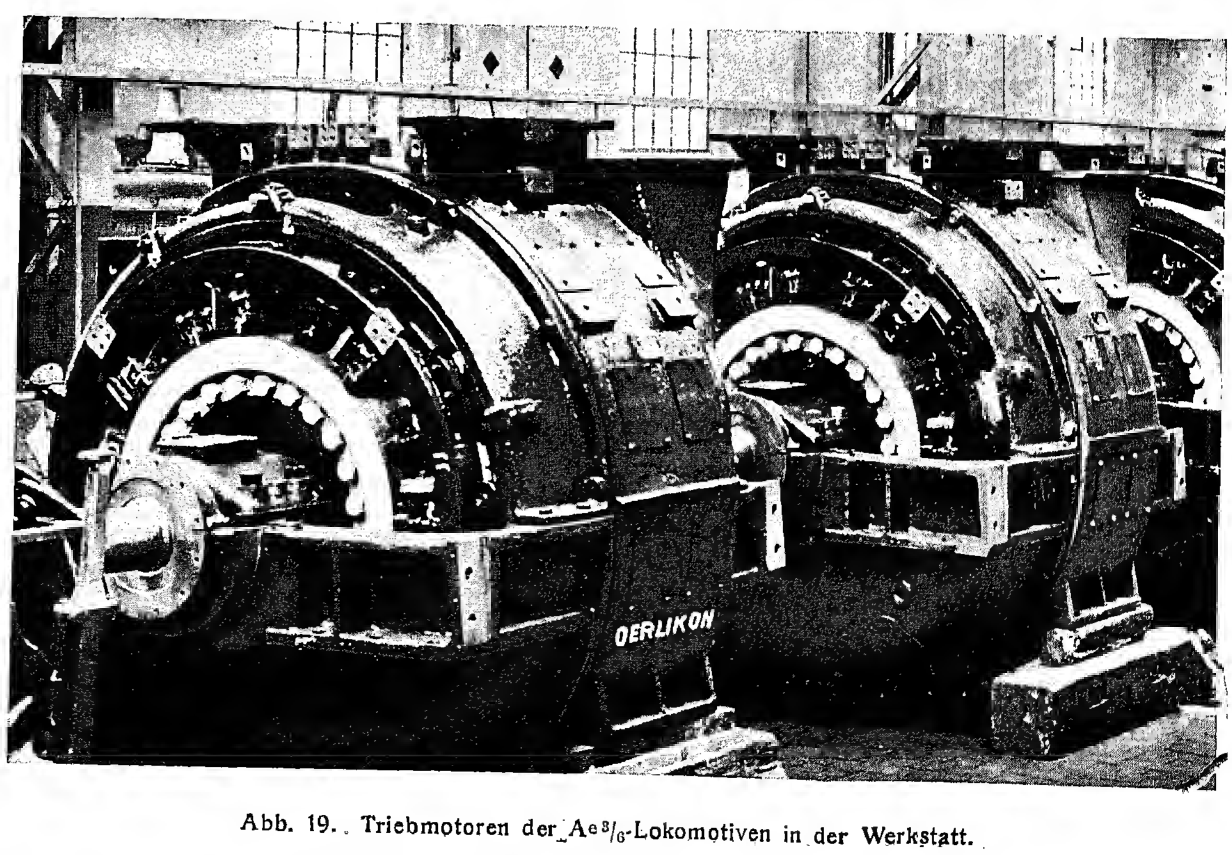


Abb. 19. Triebmotoren der A^{e} $^{3}/_{6}$-Lokomotiven in der Werkstatt.

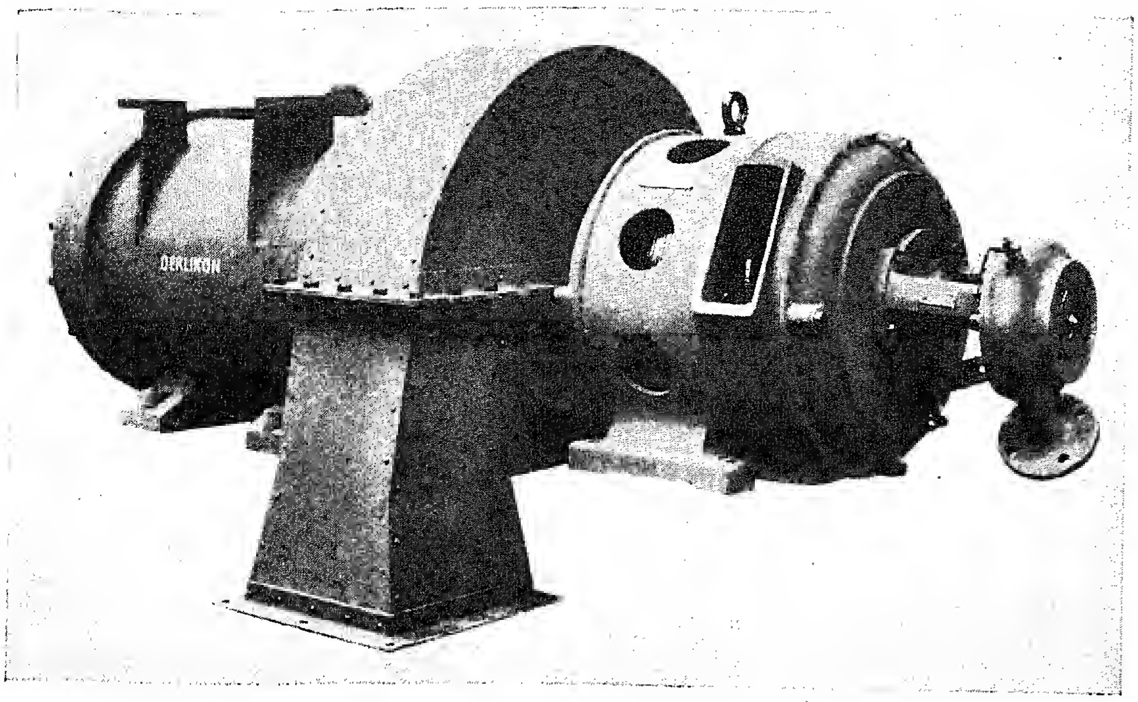


Abb. 22. Kühlgruppe mit Oelpumpe und Röhrenkühler für die Transformatoren.

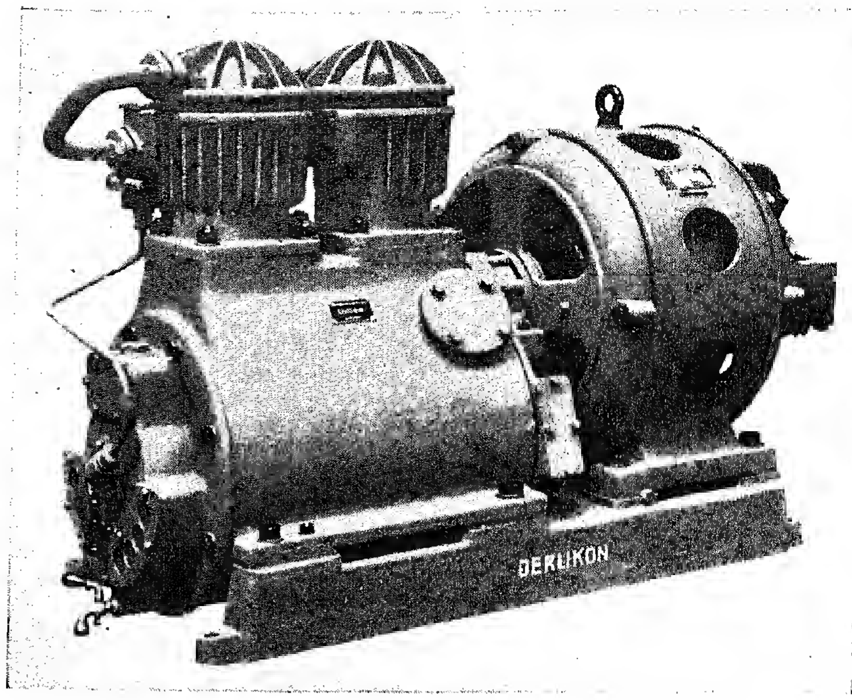


Abb. 23. Kompressor-Gruppe, Bauart Oerlikon.

Die schon erwähnte *Transformatoren-Kühlgruppe* (Abbildung 22), besteht aus dem Röhrenkühler für das Transformatorenöl (links im Bilde), dem Ventilator mit Antriebmotor und der Zentrifugal-Oelpumpe (rechts). Die Kühlluft wird aus dem Lokomotiv-Innern durch den Kühler angesaugt und mittels eines Diffusors durch den Lokomotivboden auf den Bahnkörper ausgeblasen. Um der lästigen und schädlichen Staubentwicklung beim Befahren von Bahnübergängen usw. vorzubeugen, sind beim Luftaustritt unterhalb der Lokomotive besondere Schikanen angebracht, wodurch der Luftstrom abgelenkt und unschädlich gemacht wird. Der Ventilator absorbiert eine Leistung von 11,5 PS bei rd. 1800 Uml/min und fördert dabei 150 m^3/min bei einem Gesamt-Druck von 160 mm WS. Die Zentrifugal-Oelpumpe erfordert eine Leistung von 2,5 PS und fördert nach Messungen an der fertigen Lokomotiv-Einrichtung etwa 250 l/min.

Kompressoren. Zur Erzeugung der benötigten Druckluft dienen bei den ältern Lokomotiven dieser Serie Rotations-Kompressoren, bei den neuern als Kolbenmaschinen mit schnellaufenden Antriebsmotoren nach Abb. 23 gebaute Kompressoren. Diese letzten fördern eine Luftmenge von 2000 l/min, bezogen auf Ansaugezustand und 7 at. Druck, nach 15 min Dauerbetrieb. Das im Kompressor eingebaute Zahngetriebe hat ein Uebersetzungsverhältnis von 1 : 3. Dieser von der Maschinenfabrik Oerlikon entwickelte Kompressortyp [1]) wurde auf Grund eingehender Betriebsversuche von den Schweizerischen Bundesbahnen für sämtliche Ende 1924 in Auftrag gegebenen grossen Streckenlokomotiven bei dieser Firma bestellt.

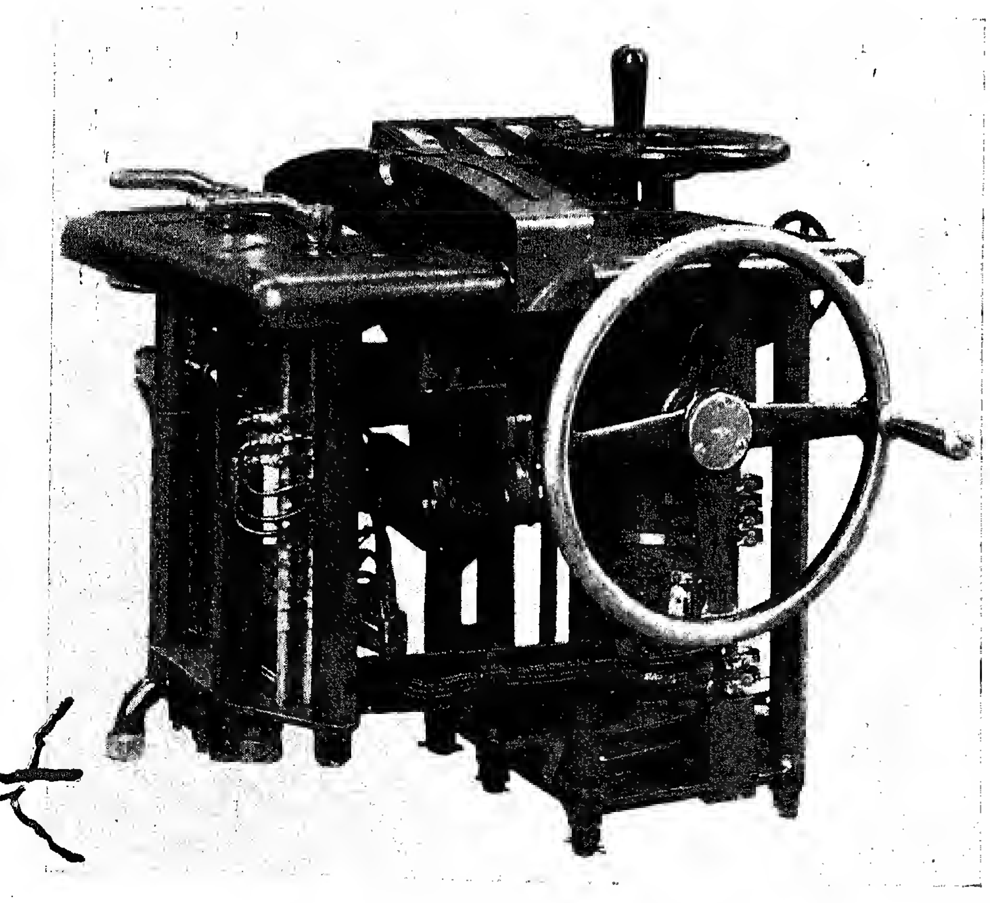


Abb. 24. Steuerkontroller.

Die *Steuerkontroller* bilden je einen kompletten Apparat mit allen für die Fortbewegung der Lokomotive vereinigten und mechanisch gegeneinander verriegelten Betätigungsschaltern für die Stromabnehmer, den Hauptschalter, die Wendeschalter und die Stufenschalter, einschliesslich der Messinstrumente für die Fahrspannung, den Fahrstrom und die beiden Triebmotoren. Die Verriegelung ist derart getroffen, dass bei Stellung „Abschluss" des Stromabnehmer-Betätigungshebels, des einzigen in der Nullstellung abnehmbaren Handgriffs, alle übrigen Vorrichtungen des Kontrollers blockiert sind.

Um die Steuerung der Lokomotive bei gesenkten Stromabnehmern gefahrlos auf ihr richtiges Arbeiten untersuchen zu können, ist ausser der Betriebstellung „Hoch" eine Stellung „Tief" des Stromabnehmer-Betätigungshebels vorhanden, in der der Steuerkontroller ebenfalls entriegelt und der Anschluss der Steuerleitungen an die Stromquelle vollzogen ist, die pneumatische Speiseleitung der Stromabnehmer dagegen, statt an die Hauptleitung angeschlossen zu sein, mit der Aussenluft in Verbindung steht, sodass die Stromabnehmer gesenkt bleiben. Die beiden Handräder der Stufenschalter-Steuerung, wovon das eine, nicht abnehmbare, für elektrische und das andere, abnehmbare, für Handsteuerung bestimmt ist, können nur betätigt werden, wenn der Wendeschalterhebel in einer der beiden Betriebstellungen „Vorwärts" oder „Rückwärts" sich befindet. Anderseits ist eine Bedienung des Wendeschalterhebels nur möglich, wenn die Stufenschalter-Steuerwalze auf Stellung „0" sich befindet, wie auch der Hauptschalterhebel nur bei Nullstellung der letztgenannten Walze auf „Ein", dagegen jederzeit auf „Aus" geschaltet werden kann. Der Hauptschalterhebel wird nach Ausführung eines Schaltmanövers durch Federkraft in seine Nullage zurückgeführt; als Rückmeldung über die jeweilige Stellung des Hauptschalters dient das Fahrspannungs-Voltmeter.

Zwischen den Stufenschaltern und dem Hauptschalter besteht eine weitere, elektrische Verriegelung, indem die Zuleitung zum Hauptschalter-Antriebsmotor über die in Serie geschalteten Hülfskontakte der Stufenschalter geführt wird, die nur in Nullstellung dieser Schalter geschlossen sind. Eine Einschaltung des Hauptschalters vom Steuerkontroller aus ist somit nur möglich, wenn beide Stufenschalter vollständig abgeschaltet sind. Die erwähnte elektrische Verriegelung verhindert falsche Schaltmanöver, z. B. wenn bei Revisionen die Stufenschalter von Hand betätigt und dann versehentlich unrichtig eingestellt wurden.

[1]) Nähere Einzelheiten über diesen neuen Kolbenkompressor siehe „Bulletin Oerlikon" vom Mai 1924.

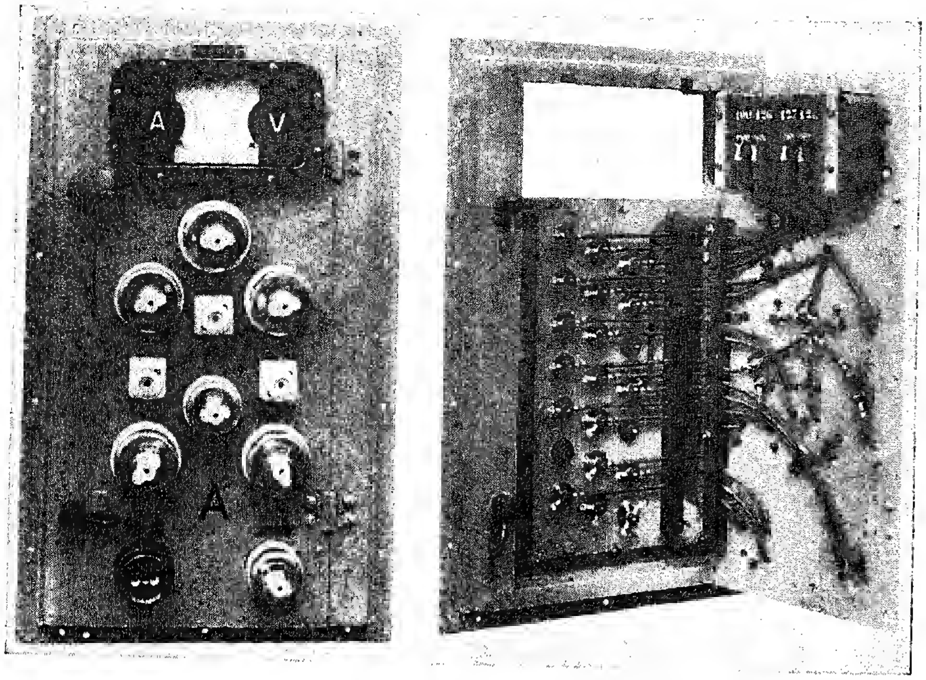


Abb. 25. Schalttafel A im Führerstand, geschlossen und offen.

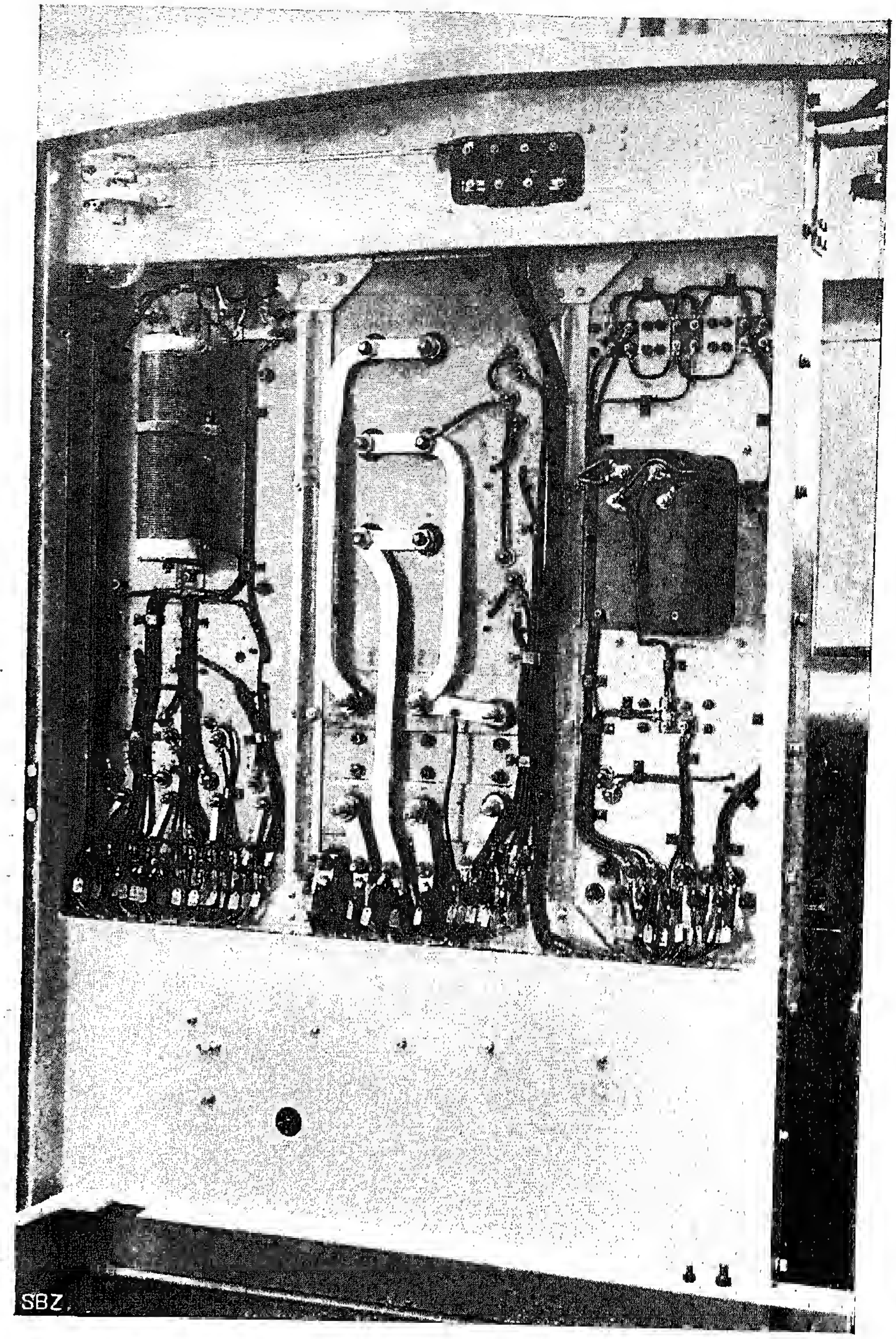


Abb. 26. Rückseite der Schalttafeln D, C und E.

Schalttafeln. Die verschiedenen Hilfsschalter mit zugehörigen Sicherungen, sowie die Auslöserelais, die Doppelinstrumente für Zugheizungs-Spannung und -Strom, das Batterie-Ampèremeter und -Voltmeter und der automatische Anlassapparat für die Motorgeneratorengruppe sind übersichtlich auf fünf Schalttafeln verteilt. In der Skizze links unten auf dem Schaltschema, Abbildung 10 (Tafel) sind zwei dieser Schalttafeln als Führerstand-Schalttafeln A, B (Abbildung 25), eine als Wechselstrom-Schalttafel C, eine als Gleichstrom-Schalttafel D und eine als Relais-Schalttafel E bezeichnet. Die drei letzten befinden sich im Innern der Lokomotive im Kompressorraum an der Trennwand gegen den Triebmotorenraum. Ueber deren praktische und schöne Leitungsführung gibt Abbildung 26 Aufschluss. Diese ferner lässt erkennen, wie die ankommenden Kabel durch kleine Karton-Etiketten bezeichnet werden. Alle Etiketten und die Anschlussklemmen sind zwecks Erleichterung der Montage und der Revisionen mit der im Schaltplan angegebenen Leitungsnummer versehen.

Als Schutz der Lokomotive gegen Ueberlastungen und Kurzschlüsse sind vorhanden: Ein Maximalstromrelais mit Zeitauslösung für den Hauptstromkreis und drei Maximalstromrelais mit Momentauslösung, wovon zwei für die beiden Triebmotoren und das dritte für die Zugheizung, sämtliche auf den Auslöstromkreis des Hauptschalters wirkend.

Der nun seit längerer Zeit in grösserer Anzahl in regulärem Dienst stehende Lokomotiv-Typ $A^{e}\,{}^{3}/_{6}{}^{II}$ hat sich als ein vorzügliches Triebfahrzeug erwiesen. Vor allem ist sein guter Kurvenlauf hervorzuheben; besondere Versuchsfahrten auf der kurvenreichen Strecke zwischen Zug und Arth-Goldau haben gezeigt, dass die Lokomotive den Krümmungen des Geleises nach beiden Fahrrichtungen, d. h. bei Führung durch das zweiachsige Drehgestell oder durch das einachsige Bisselgestell in gleicher Weise ohne harte Stösse oder Erschütterungen zu folgen vermag. Der Grund dieses guten Kurvenlaufes ist einerseits in der gewählten Unterteilung der Federabstützung der Lokomotive, anderseits aber vor allem in dem Umstande zu suchen, dass die schweren Motoren mit dem Antrieb und der Transformator möglichst gegen die Lokomotivmitte hin konzentriert und hoch im Rahmen gelagert sind, sodass sich eine hohe Schwerpunktslage der Lokomotive ergibt. Der Antriebsmechanismus arbeitet dank der guten Lagerung der Vorgelegewellen und der weichen, in die Zahnkolben eingebauten Federung bei allen Geschwindigkeiten ohne jede Stösse und Vibrationen.

Bis jetzt sind 32 Lokomotiven dieser Serie abgeliefert und in Betrieb, davon die ersten 15 seit mehr als einem Jahr; sie entsprechen auch in Bezug auf den elektrischen Teil allen an sie gestellten Anforderungen.

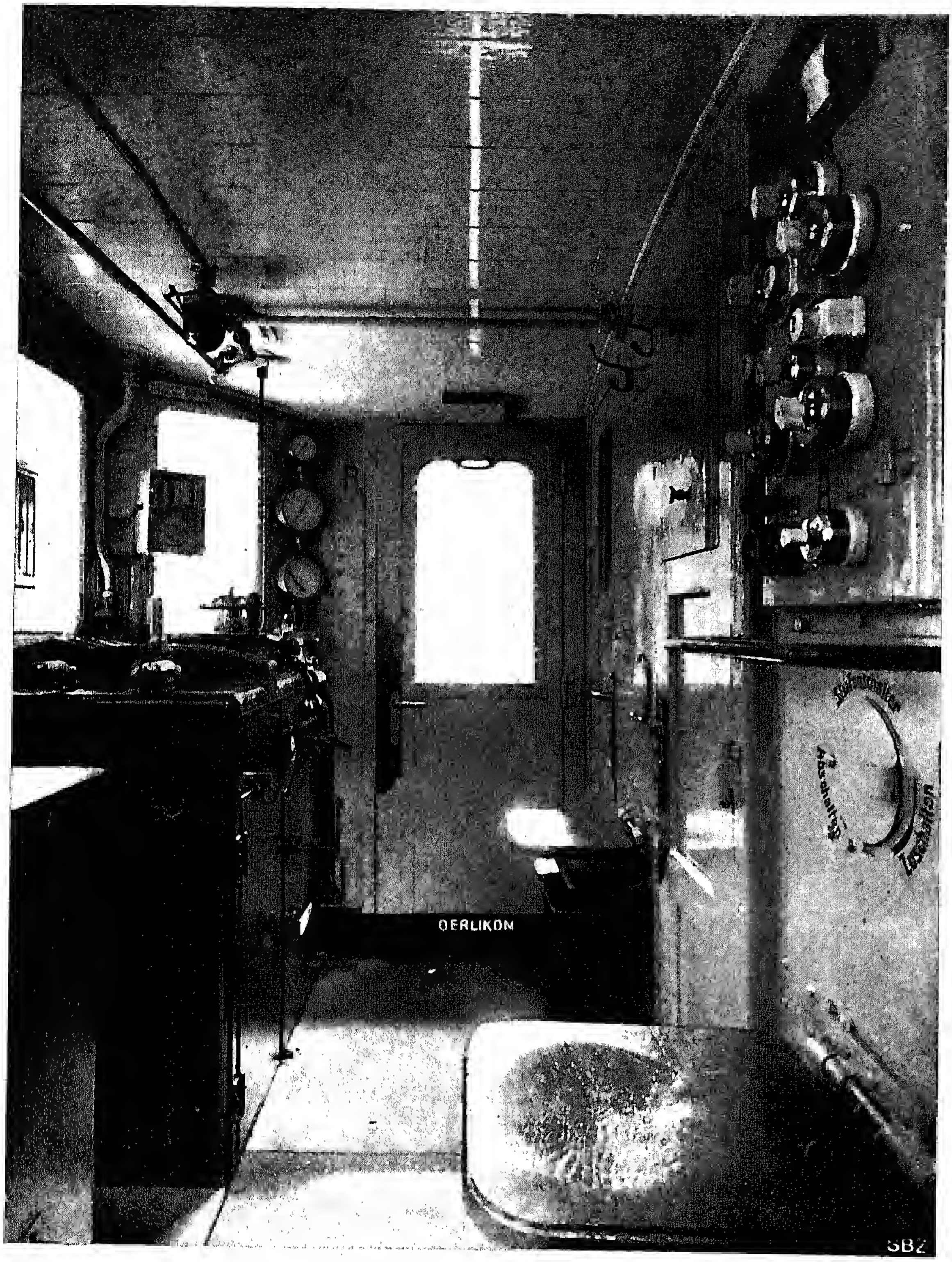


Abb. 27. Führerstand I der Ae $^3/_6$-Schnellzug-Lokomotiven.

BULLETIN OERLIKON

No. 58 — April 1926

Contents: Motor Coach Trains of the London Electric Railway.
Notes and News Items: 750000 Volt Testing Plant.

Fig. 1. Six-coach trains of the London Electric Railway.

Motor Coach Trains of the London Electric Railway.

In the spring of 1924, and in the course of 1925, the London Electric Railway Company placed orders for 95 motor coaches, 78 trailer coaches with driver's cab and 55 ordinary trailer coaches, for operating the new Morden extension of the City and South London Railway, as well as for service on the Piccadilly and Golders Green lines. The electrical part of these coaches was supplied by the General Electric Co. Ltd., who built the equipments under licence to the designs of the Oerlikon Company. The traction system is direct current at 530/600 volts. As the new motor coaches had to be suitable for use with the existing rolling stock on the lines in question, and their operation ensured by means of multiple control, the mode of connection of motors and gear was fixed from the outset. It was further laid down that the motor coaches were to be so arranged as to permit of the automatic control of any train composition — four, six or seven-coach trains — while provision was also to be made for non-automatic control for shunting operations. The following are the main particulars of motor coaches:—

Hourly output measured at wheel rim	480 HP at 19.6 m.p.h.
Hourly tractive effort measured at wheel rim	9200 lbs.
Maximum tractive effort at start	15400 lbs.
Maximum speed	50 m.p.h.
Average speed	20 m.p.h.
Acceleration at start	1.40 miles/h/sec.
Average line pressure	575 volts.
Minimum line pressure	400 volts.
Gauge	4' 8 1/2".
Diameter of driving wheels	3' 4".
Length over buffers	50 ft.
Weight of the electrical equipment	10 tons.
Weight of the mechanical part	20 tons.
Weight of the motor coach	30 tons.
Weight of passengers	3 tons.

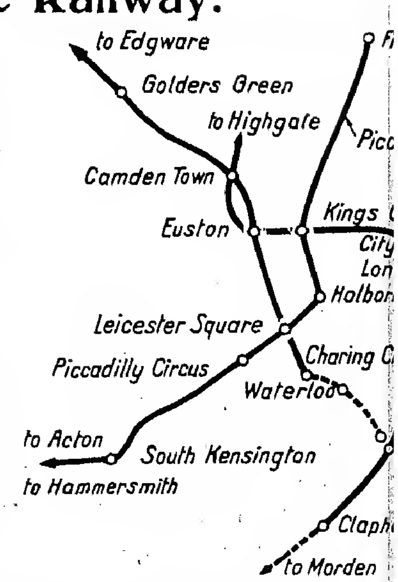


Fig. 2. Simplified map of the City London Railway, and the Pic Golders Green lines of the Lond Railway Co.

Mechanical Part. One of the special features of the motor coaches is compactness of design, a condition imposed by the tunnels, which are circular in section, and have a diameter of only 11 ft. 8¹/₄ ins. For safety reasons, the coaches are made entirely of steel. The coach body is carried by two four-wheel bogies, the two driving motors being mounted on one of the bogies. In order to obtain the necessary clearance for the driving bogie, the floor of the apparatus cabin is disposed about 1 ft. 6 ins. higher than that of the passenger compartment and the driver's cab. The apparatus cabin is arranged immediately behind the driver's cab and provided on either side with louvres for ventilation purposes. Doors are fitted at both ends of the apparatus cabin, in the centre, so as to enable the train staff to pass right through the coach. The passenger compartment of motor coaches is provided with two large doors, one on each side, half-way down the coach, apart from the 2 smaller doors at the end remote from the apparatus cabin, while the trailer coaches have four. All coaches are equipped with automatic and hand brake. The coaches are heated electrically, the current supply for this purpose, as well as that for the lighting, being derived from the motor coach. For safety reasons, too, all cables are run in steel pipes, and the connections made in totally enclosed junction boxes. The driving bogies are of the standard British type and their fixed wheel base measures 6′4″. The centre bolster is spring borne and the bogie is supported by the axle boxes through the intermediary of laminated springs.

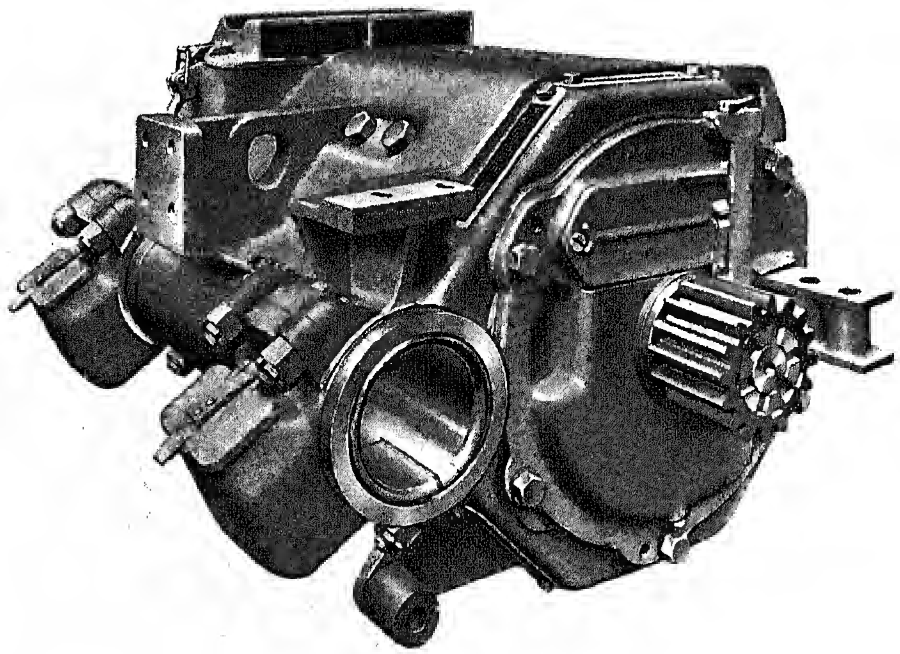


Fig. 3. Self-ventilated geared motor, 240 HP one-hour rating.

Electrical Equipment. The whole electrical control apparatus is concentrated in the apparatus cabin. The current is collected from positive and negative conductor rails located, respectively at the side of the track and between the two running rails. The four positive contact shoes are secured to wooden beams resting directly on the axle boxes. Isolating switches are provided in the main circuit immediately after the contact shoes, by means of which it is possible to disconnect from the supply the whole electrical apparatus, without interfering with the operation of the gear on the other motor coaches worked with the multiple control. The lighting, heating, compressor and no-volt relay circuits branch off between the contact shoes and isolating switches, so that these circuits are not cut off from the supply when the isolating switches are open. The driving motors, starting resistances and contactors are protected by means of two main fuses. A further safeguard is afforded by the two main circuit breakers, one on each pole, which are designed with double break and fitted with overload release. These main circuit breakers are provided with magnetic blow-out and operated electro-magnetically from the driver's cab. The control of starting process is ensured by means of 12 contactors per motor coach; the latter are also fitted with magnetic blow-out and actuated electro-magnetically. Their nominal rupturing capacity is 400 amps at 600 volts; tests have, however, shown that they could interrupt without difficulty 800 amps at 600 volts. For the automatic control of switching process, provision has been made on each contact for four interlocking contacts which are operated mechanically by the contactor. The starting resistances are built up of cast iron units, arranged in boxes, in sets of 20. Either motor can be cut out by means of a double-throw isolating switch, without this interfering with the switching process, the remaining motor being then controlled until full voltage is applied to its terminals. The starting up process, during automatic operation, is controlled by means of a current limiting relay; the latter actuates alternatively two sets of contacts, which in turn bring the contactors into play. The direction of rotation of motors is changed by means of a double reverser, operated electro-magnetically.

Both driving motors are, as stated before, mounted on one bogie; each machine can develop an hourly output of 240 HP measured at wheel rim. The tests, as well as the trial runs carried out when the motor coaches were taken over, have shown that the heating of motors is far below the permissible limits. The motors are enclosed and designed with double-flow self ventilation; they are supported on one side by bearings on the driving axles and rest on the other side directly on the bogie transom through the intermediary of lugs or noses on the motor frame. The reduction gear, which is arranged on one side of motor is of steel, both pinion and spur wheel being of the solid type. The gear ratio is 1:4.19. The speed, in the case of the one-hour rating, with an average pressure of 575 volts, is 680 r.p.m. The efficiency of the motor is 89% at full load including the losses in the reduction gear. The maximum speed is 750 r.p.m., which corresponds to a train speed of 50 m.p.h. The motors are provided with only two brush-holders, an arrangement which facilitates the inspection of commutator and brushes. The armature winding is a bar winding with mica insulation; the latter is prepared by a new process, by means of which it is possible to render the winding so compact and to make it fit so accurately in

the slots that all danger of the bars vibrating and, consequently, of the insulation getting damaged is eliminated. Furthermore, the bars are firmly held in the slots by steel wire bands at four places. In order to ensure good commutation, the motors are fitted with interpoles; the cross-section of the copper conductors used for the windings of the interpoles is the same as for the main poles.

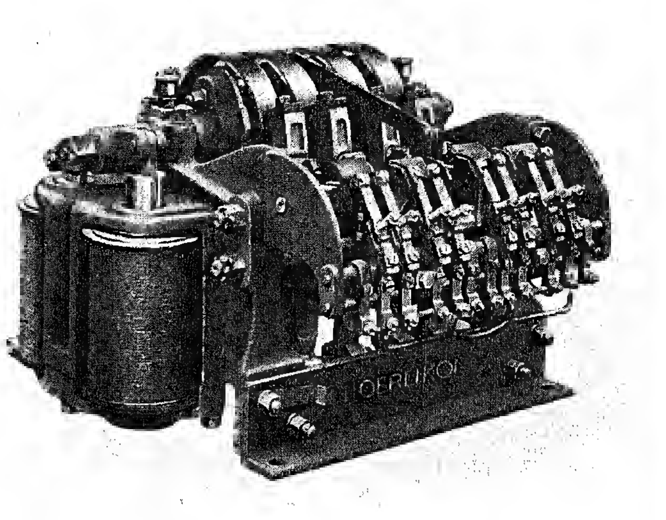


Fig. 4. Electro-magnetically operated reverser.

The master controller is built for automatic operation and comprises a control drum and a reverser drum. The control drum is arranged concentrically on the spindle carrying the operating hand, and can revolve about it freely. When, however, the "dead man's handle" device is depressed, the whole drum is raised by a special mechanism and the drum coupled to the spindle by two claws which come and engage corresponding slots. If the handle is now moved, the drum is carried along with it and the corresponding switching operations can take place. The controller itself has only four positions; the connections for the intermediate steps are ensured automatically by means of auxiliary contacts on the contactors. The control drum is further interlocked with the reverser drum in such a way that the former can only be actuated when the latter is set for "forward" or "reverse" operation. Should the dead man's handle device be released in any running position, the control drum drops down, the claws securing the drum to the spindle become disengaged and the drum is brought back automatically to the "off" position, through the action of a spring, with the result that the motors are switched off. At the same time, the brake valve opens, so that the train is brought automatically to a standstill. When starting up again, the handle of the controller has first to be moved back to the "off" position, after which the switching operations can be started afresh.

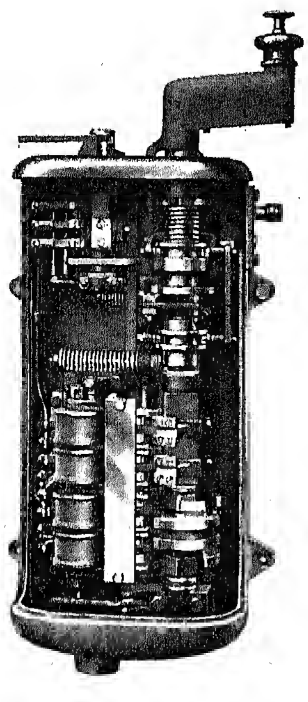


Fig. 5. Master controller with "dead man's handle" device.

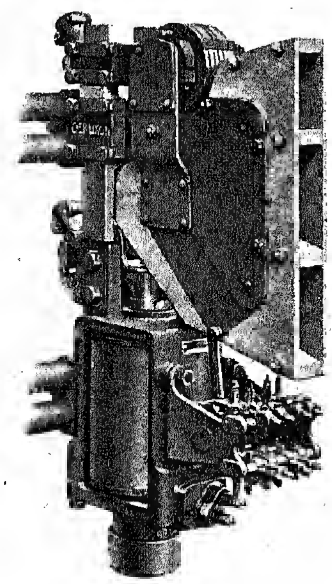


Fig. 6. Electro-magnetically operated contactor.

The control circuits of the contactors and reverser as well as of the main circuit breakers are fed directly by the 600 volt supply. In order that the resistance of the individual circuits should remain approximately constant, the contactor coils which are cut out are replaced by corresponding resistances. The passage from one step to the next takes place without interruption of the main circuit. A minimum pressure relay is provided, which comes into play at a pressure of 400 volts or lower. This relay is fitted with a time lag device which delays its closing after an interruption, thus ensuring that all contactors drop out; the latter are then only permitted to re-close in sequence under the control of the accelerating relay. Hence, when crossing short gaps in the conductor rails, undesirable rushes of current are avoided.

Cran	Pos	CB	M1	10	G	M2	JR	J	RR1	R1	RR2	R2	RR3	R3
0	0	●												
1	1	●	●	●			●							
	2	●	●	●			●		●					
	3	●	●	●			●		●	●				
	4	●	●	●			●		●	●	●			
	5	●	●	●			●		●	●	●	●		
	6	●	●	●			●		●	●			●	●
		●	●	●			●	●	●	●			●	●
2	7	●	●	●				●						
		●	●	●	●	●		●						
3	8	●	●	●	●	●								
	9	●	●	●	●	●			●					
	10	●	●	●	●	●			●	●				
	11	●	●	●	●	●			●	●	●			
	12	●	●	●	●	●			●	●	●	●		
4	13	●	●	●	●	●			●	●			●	●

Sh Contact shoes.
MS Isolating switch.
F Fuses.
M, G, R, J, 10 Contactors.
CB Main circuit breaker.
1,2 Motors.
CO Isolating switches of motors.
R Coupling plugs.

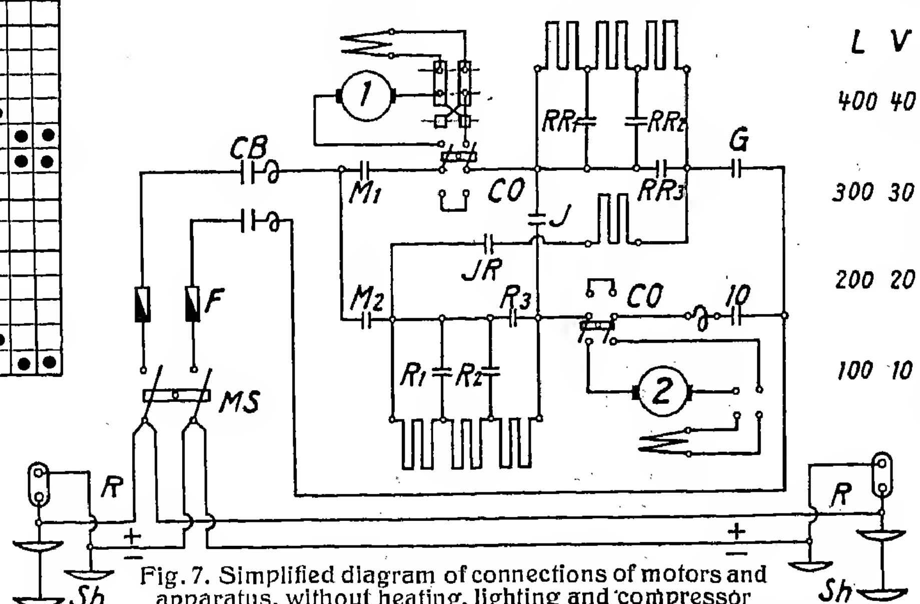


Fig. 7. Simplified diagram of connections of motors and apparatus, without heating, lighting and compressor circuits.

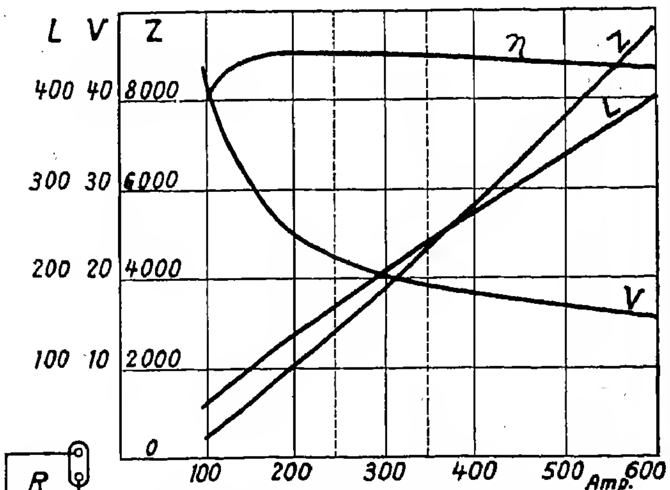


Fig. 8. Characteristic curves of motors.
L = Output measured at wheel rim, in HP.
Z = Tractive effort, in lbs.
V = Speed, in m.p.h. η = Efficiency.

Mechanical Part. One of the special features of the motor coaches is compactness of design, a condition imposed by the tunnels, which are circular in section, and have a diameter of only 11 ft. $8^1/_4$ ins. For safety reasons, the coaches are made entirely of steel. The coach body is carried by two four-wheel bogies, the two driving motors being mounted on one of the bogies. In order to obtain the necessary clearance for the driving bogie, the floor of the apparatus cabin is disposed about 1 ft. 6 ins. higher than that of the passenger compartment and the driver's cab. The apparatus cabin is arranged immediately behind the driver's cab and provided on either side with louvres for ventilation purposes. Doors are fitted at both ends of the apparatus cabin, in the centre, so as to enable the train staff to pass right through the coach. The passenger compartment of motor coaches is provided with two large doors, one on each side, half-way down the coach, apart from the 2 smaller doors at the end remote from the apparatus cabin, while the trailer coaches have four. All coaches are equipped with automatic and hand brake. The coaches are heated electrically, the current supply for this purpose, as well as that for the lighting, being derived from the motor coach. For safety reasons, too, all cables are run in steel pipes, and the connections made in totally enclosed junction boxes. The driving bogies are of the standard British type and their fixed wheel base measures 6′4″. The centre bolster is spring borne and the bogie is supported by the axle boxes through the intermediary of laminated springs.

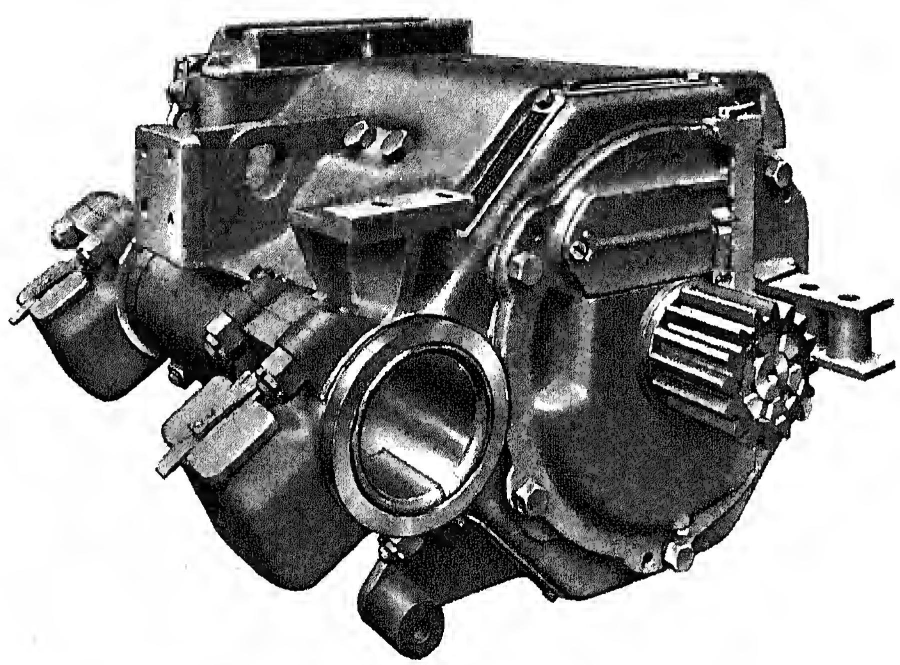


Fig. 3. Self-ventilated geared motor, 240 HP one-hour rating.

Electrical Equipment. The whole electrical control apparatus is concentrated in the apparatus cabin. The current is collected from positive and negative conductor rails located, respectively at the side of the track and between the two running rails. The four positive contact shoes are secured to wooden beams resting directly on the axle boxes. Isolating switches are provided in the main circuit immediately after the contact shoes, by means of which it is possible to disconnect from the supply the whole electrical apparatus, without interfering with the operation of the gear on the other motor coaches worked with the multiple control. The lighting, heating, compressor and no-volt relay circuits branch off between the contact shoes and isolating switches, so that these circuits are not cut off from the supply when the isolating switches are open. The driving motors, starting resistances and contactors are protected by means of two main fuses. A further safeguard is afforded by the two main circuit breakers, one on each pole, which are designed with double break and fitted with overload release. These main circuit breakers are provided with magnetic blow-out and operated electro-magnetically from the driver's cab. The control of starting process is ensured by means of 12 contactors per motor coach; the latter are also fitted with magnetic blow-out and actuated electro-magnetically. Their nominal rupturing capacity is 400 amps at 600 volts; tests have, however, shown that they could interrupt without difficulty 800 amps at 600 volts. For the automatic control of switching process, provision has been made on each contact for four interlocking contacts which are operated mechanically by the contactor. The starting resistances are built up of cast iron units, arranged in boxes, in sets of 20. Either motor can be cut out by means of a double-throw isolating switch, without this interfering with the switching process, the remaining motor being then controlled until full voltage is applied to its terminals. The starting up process, during automatic operation, is controlled by means of a current limiting relay; the latter actuates alternatively two sets of contacts, which in turn bring the contactors into play. The direction of rotation of motors is changed by means of a double reverser, operated electro-magnetically.

Both driving motors are, as stated before, mounted on one bogie; each machine can develop an hourly output of 240 HP measured at wheel rim. The tests, as well as the trial runs carried out when the motor coaches were taken over, have shown that the heating of motors is far below the permissible limits. The motors are enclosed and designed with double-flow self ventilation; they are supported on one side by bearings on the driving axles and rest on the other side directly on the bogie transom through the intermediary of lugs or noses on the motor frame. The reduction gear, which is arranged on one side of motor is of steel, both pinion and spur wheel being of the solid type. The gear ratio is 1:4.19. The speed, in the case of the one-hour rating, with an average pressure of 575 volts, is 680 r.p.m. The efficiency of the motor is 89% at full load including the losses in the reduction gear. The maximum speed is 750 r.p.m., which corresponds to a train speed of 50 m.p.h. The motors are provided with only two brush-holders, an arrangement which facilitates the inspection of commutator and brushes. The armature winding is a bar winding with mica insulation; the latter is prepared by a new process, by means of which it is possible to render the winding so compact and to make it fit so accurately in

the slots that all danger of the bars vibrating and, consequently, of the insulation getting damaged is eliminated. Furthermore, the bars are firmly held in the slots by steel wire bands at four places. In order to ensure good commutation, the motors are fitted with interpoles; the cross-section of the copper conductors used for the windings of the interpoles is the same as for the main poles.

The master controller is built for automatic operation and comprises a control drum and a reverser drum. The control drum is arranged concentrically on the spindle carrying the operating hand, and can revolve about it freely. When, however, the "dead man's handle" device is depressed, the whole drum is raised by a special mechanism and the drum coupled to the spindle by two claws which come and engage corresponding slots. If the handle is now moved, the drum is carried along with it and the corresponding switching operations can take place. The controller itself has only four positions; the connections for the intermediate steps are ensured automatically by means of auxiliary contacts on the contactors. The control drum is further interlocked with the reverser drum in such a way that the former can only be actuated when the latter is set for "forward" or "reverse" operation. Should the dead man's handle device be released in any running position, the control drum drops down, the claws securing the drum to the spindle become disengaged and the drum is brought back automatically to the "off" position, through the action of a spring, with the result that the motors are switched off. At the same time, the brake valve opens, so that the train is brought automatically to a standstill. When starting up again, the handle of the controller has first to be moved back to the "off" position, after which the switching operations can be started afresh.

The control circuits of the contactors and reverser as well as of the main circuit breakers are fed directly by the 600 volt supply. In order that the resistance of the individual circuits should remain approximately constant, the contactor coils which are cut out are replaced by corresponding resistances. The passage from one step to the next takes place without interruption of the main circuit. A minimum pressure relay is provided, which comes into play at a pressure of 400 volts or lower. This relay is fitted with a time lag device which delays its closing after an interruption, thus ensuring that all contactors drop out; the latter are then only permitted to re-close in sequence under the control of the accelerating relay. Hence, when crossing short gaps in the conductor rails, undesirable rushes of current are avoided.

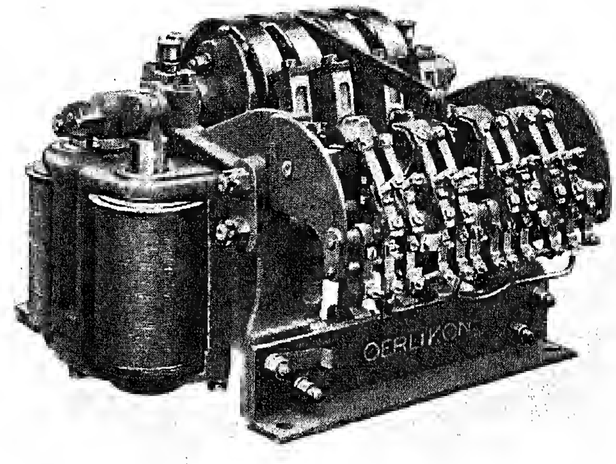
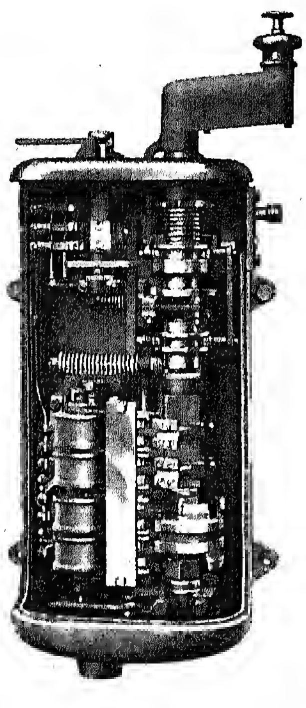


Fig. 4. Electro-magnetically operated reverser.



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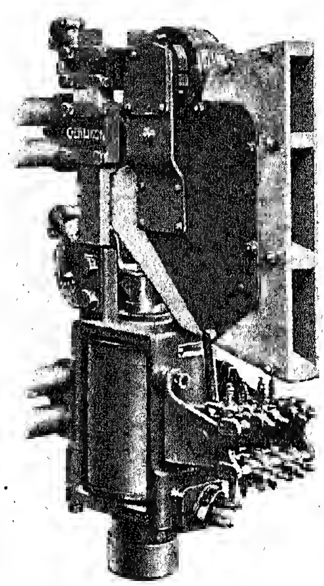

Fig. 6. Electro-magnetically operated contactor.

Cran	Pos	CB	M1	10	G	M2	JR	J	RR1	R1	RR2	R2	RR3	R3
0	0	●												
1	1	●	●	●			●							
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	4	●	●	●			●		●	●	●			
	5	●	●	●			●		●	●	●	●		
	6	●	●	●			●		●	●			●	●
		●	●	●			●	●	●	●			●	●
2	7	●	●	●				●						
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	10	●	●	●	●	●			●	●				
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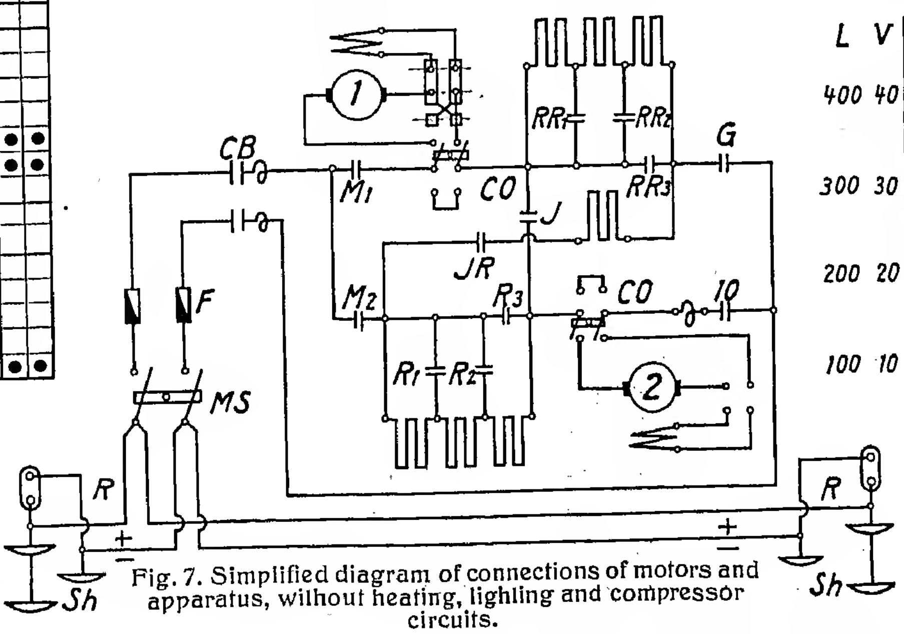

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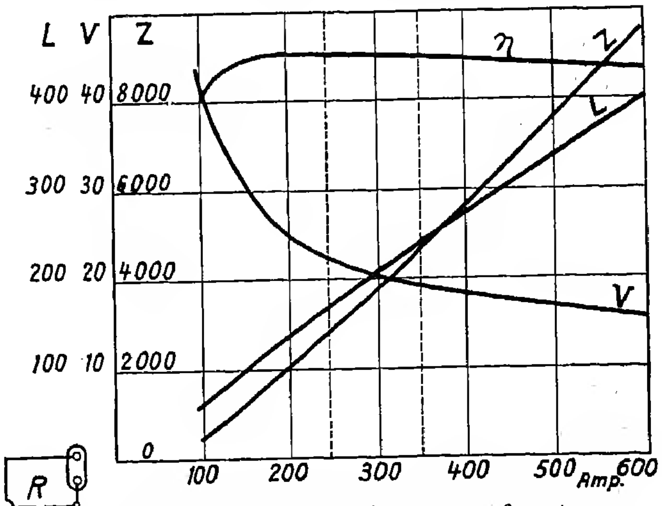


Fig. 8. Characteristic curves of motors.
L = Output measured at wheel rim, in HP.
Z = Tractive effort, in lbs.
V = Speed, in m.p.h. η = Efficiency.

Notes and News Items.

750000 Volt Testing Plant. The plant in question, which is represented on this page, was recently built by the Oerlikon Company for the Université Libre, Brussels. The whole equipment was erected before despatch at the Works, where a few guests of the Company had the opportunity of viewing this interesting installation.

The plant comprises three oil immersed single-phase transformers arranged in series for a total pressure of 750000 volts, one pole being earthed. The transformers are mounted on insulating supports of impregnated wood, the latter being treated with a special oil having the property of becoming entirely resinous after the impregnation process; in view of this, there can be no subsequent leakage of oil, as in the case of ordinary impregnated woods. The bushings of transformers are ordinary tubes of resinous paper without condenser sheaths. The three transformers are identical and interchangeable at will. The H.T. windings of the three transformers consist, in all, of about 100000 turns of copper strip with paper and cotton insulation. The total length of the copper strip used for the windings amounts to about 93 miles. Each transformer is designed for a continuous rating of 75 KVA at 340/250000 volts and has an overload capacity of 100 KVA for 2 hours. The plant can be used for any of the following conditions, by arranging the units as below: —

1)	75 KVA	250000 volts	1 transformer alone
2)	75 KVA	500000 volts	2 transformers in series
3)	75 KVA	750000 volts	3 transformers in series
4)	150 KVA	250000 volts	2 transformers in parallel
5)	225 KVA	250000 volts	3 transformers in parallel
6)	225 KVA	430000 volts	3 transformers star-connected for three-phase operation, with neutral point of H. T. winding earthed.

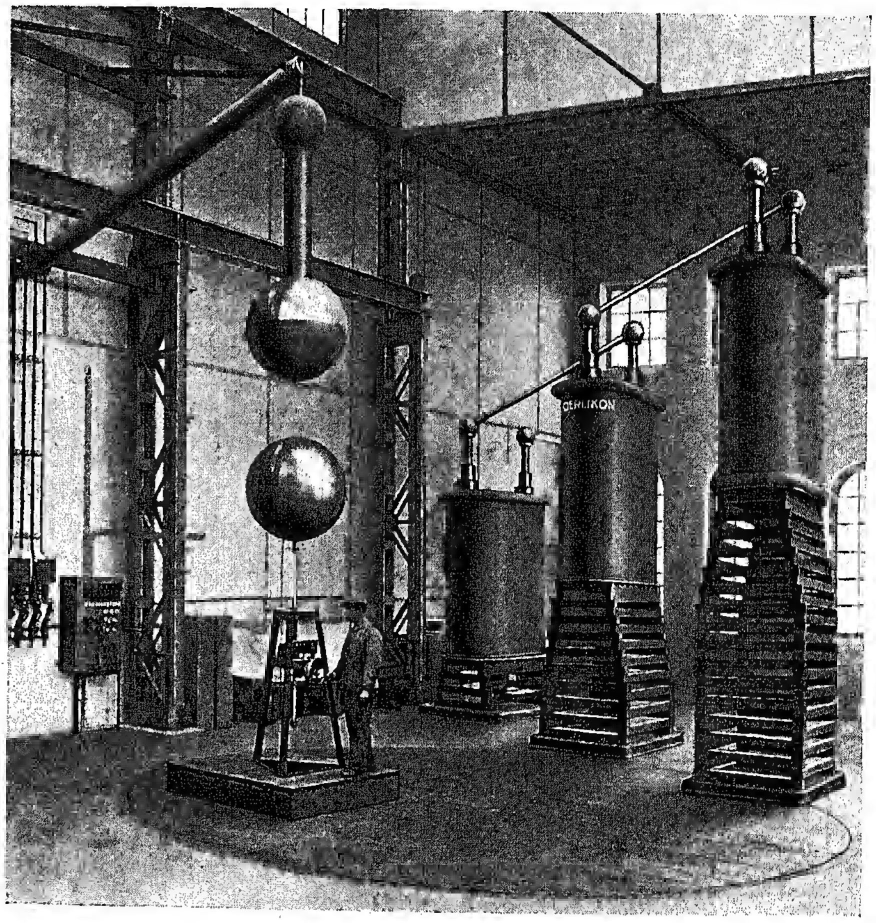
A pressure of 1500000 volts would be obtainable by using two similar sets of transformers connected as under 3. The highest permissible pressure, with the units connected in series for 750000 volts, is 900000 volts for one minute, the plant being arranged in the usual way, with one pole earthed.

Spark Gap. The H. T. pressure is measured by means of a spark gap; the latter consists of two spheres 3′ 3 3/8″ (1000 mm) in diameter, arranged one above the other, the lower one being connected to earth and the upper one to the H. T. terminal of third transformer. The two half spheres facing each other, between which the discharge takes place, are of cast copper, while the other half spheres are made of aluminium, in order to reduce the weight. Each sphere weighs about 505 lbs. The lower sphere is mounted on a vertical spindle and can be raised or lowered by means of a small servo-motor or by hand, the gap being variable, at will, between 0 and 3′ 3 3/8″ (1000 mm). In order to be able to determine also the pressure, without the need of a discharge across the spark gap, a small concentric calotte, 1′ 5 11/16″ (450 mm) in diameter, is fitted at the top of the lower sphere, from which it is insulated. The value of pressure is then obtained by measuring the capacity current flowing over the calotte, by means of a milli-ammeter used in conjunction with rectifier tubes.

The upper sphere of the spark gap is suspended from a side-bracket about 14′ 9″ (4.5 m) long, instead of being secured to the ceiling, as is usually the case; with the arrangement adopted, the crane runway above the spark gap remains clear so that the crane can travel without hindrance. The bracket, to which the upper sphere is suspended, is made of compressed resinous paper tubing, metallic parts being entirely dispensed with.

For the purpose of the tests, temporary arrangements were made for a limiting resistance for the spark gap. This resistance, which was built up of three water-filled rubber pipes, each 16′ 5″ (5 m) long, connected in series, had a value of about 800000 to 900000 ohms.

Tests. Tests were carried out with the three transformers connected in series for 750000 volts and one pole earthed; discharges were produced across the spark gap at pressures up to 800000 volts, the distance between spheres being 1′ 10 13/16″ (580 mm) for the latter pressure and 1′ 8 3/8″ (520 mm) for the normal pressure of 750000 volts. Disruptive as well as brush discharges could be obtained by altering the mode of connection of the induction regulator through which the current was supplied. Discharges were also produced between sparking points, for the purpose of comparing the results thus arrived at with those obtained with the spheres; at 750000 volts, the discharge took place with the points set at a distance of 6′ 2 13/16″ (1900 mm). The strength of the field in the neighbourhood of the spheres of the spark gap may be gauged from the fact that, even at 13′ 1″ (4 m) from it, discharges took place in a spark gap with one point entirely insulated and the other connected to earth, across a distance of 7 13/16″ (200 mm), as soon as the pressure reached 750000 volts.



Testing transformers for 750000 volts and spark gap.

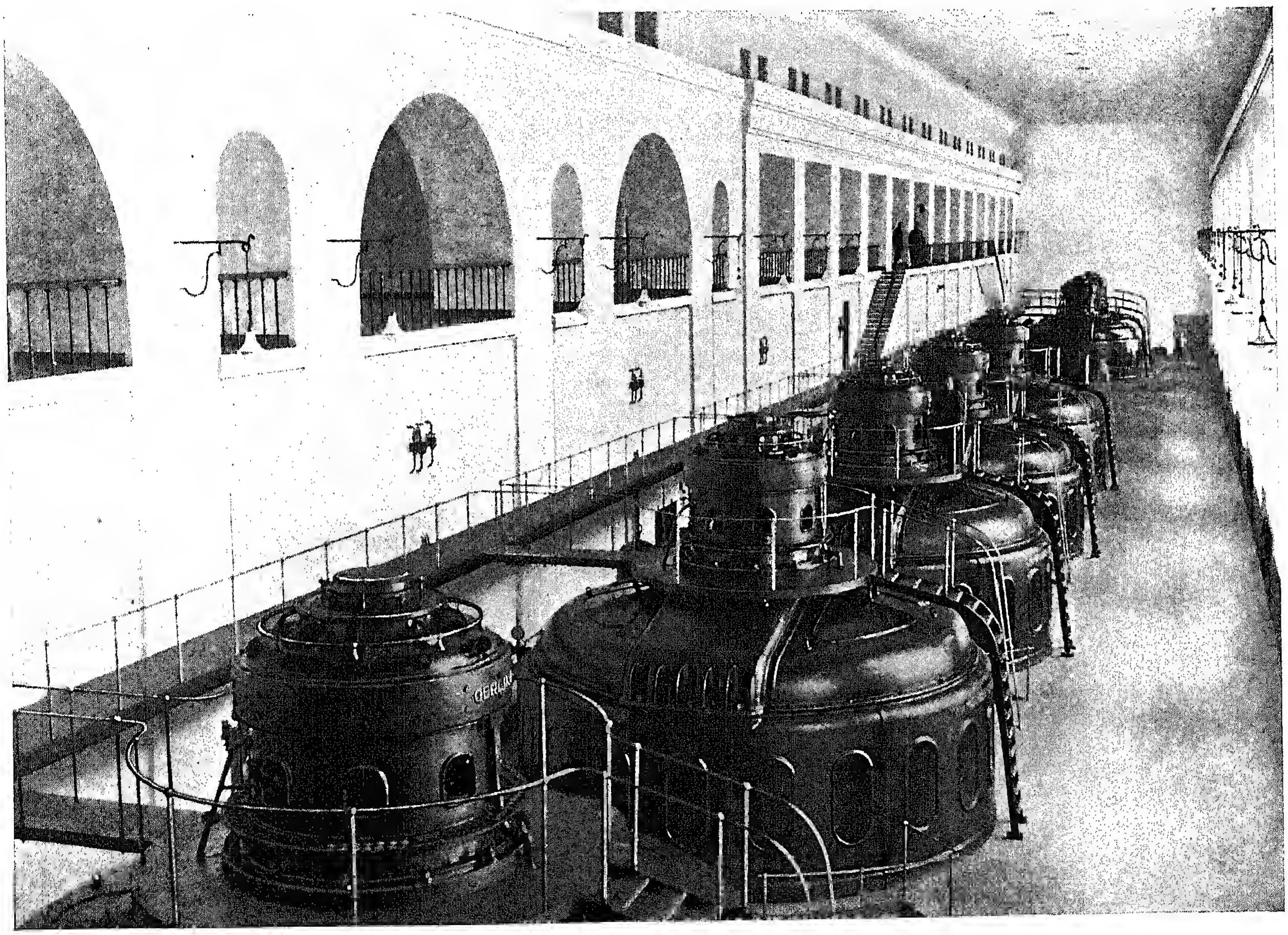
Immediately after these tests, a few breakdown tests were carried out on two built-up porcelain insulators, one of these being 8′ 8″ (2900 mm) high and the other 6′ 6 11/16″ (2000 mm) high. With the former, the breakdown occurred at a pressure of 700000 to 780000 volts and, with the latter, at 620000 to 660000 volts.

BULLETIN OERLIKON

No. 59/60 — May/June 1926

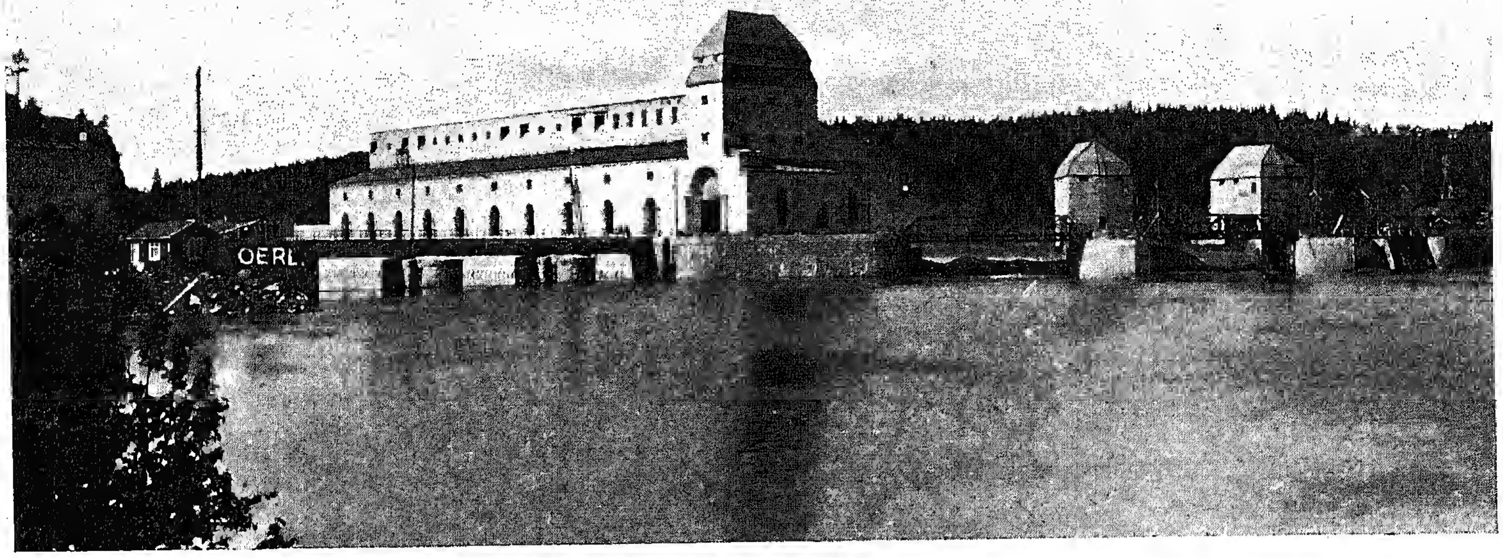
Contents: The Mörkfos-Solbergfos power station, Norway.

Notes and News Items: Fans and blowers. — Recent developments in the design of tram motors.

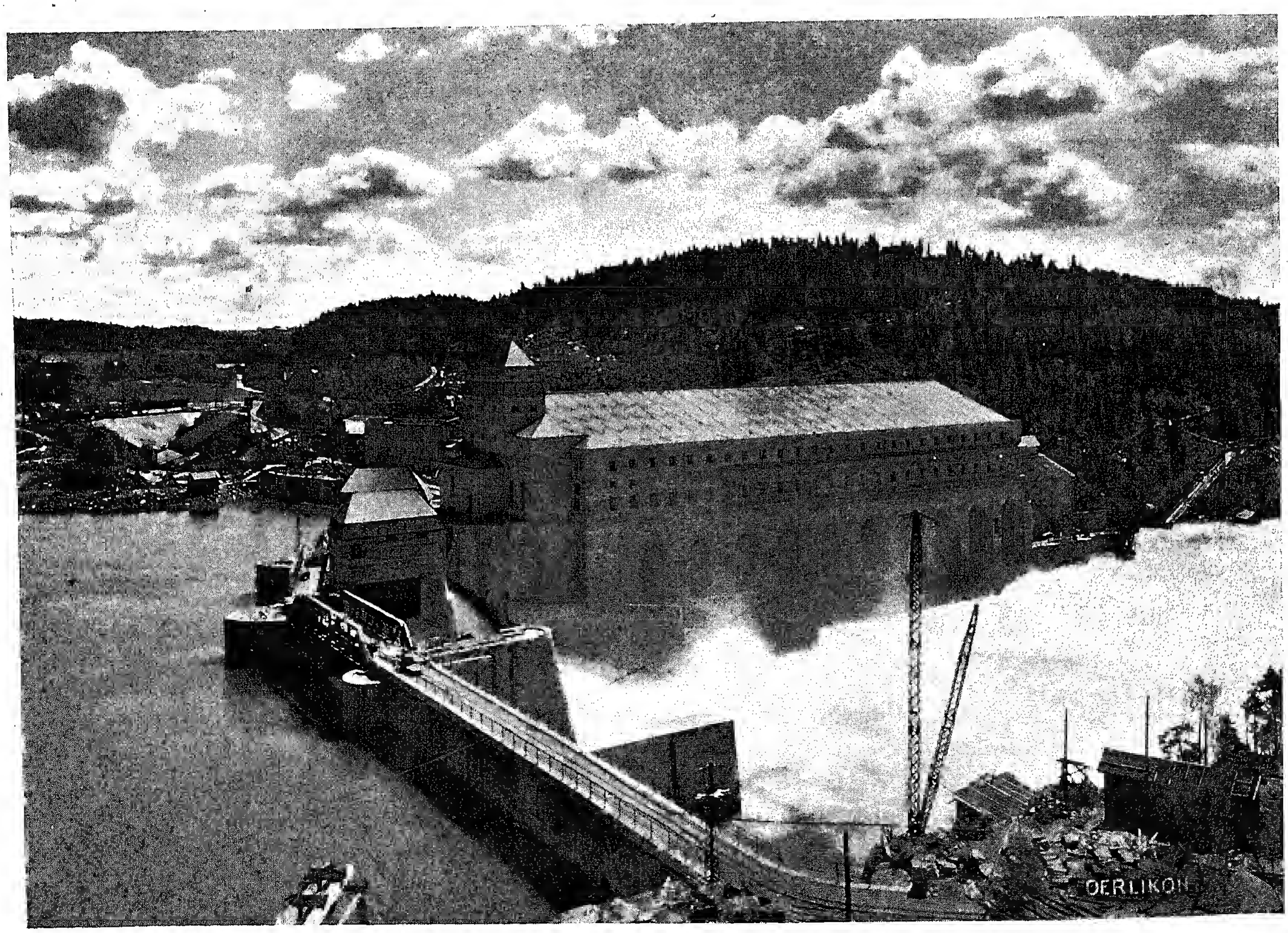


Mörkfos-Solbergfos power station.

View of machine room with the seven 10,000—11,000 KVA generators provided for in the initial programme of construction. Spare floor space has been set aside between the fifth and sixth unit for accommodating further sets, when the installation is fully developed.



View of the Mörkfos-Solbergfos power station and dam, taken from the upstream side.



View of the Mörkfos-Solbergfos power station and dam, taken at high water.

The Mörkfos-Solbergfos Power Station, Norway.

On the 1st. November of last year, the seventh three-phase generator built by the Oerlikon Company for the Mörkfos-Solbergfos power station was put into service, the unit in question being the last provided for in the initial programme of construction of this installation. Since then, all seven generators have been working continuously day and night, at full load, and have proved entirely satisfactory in every respect.

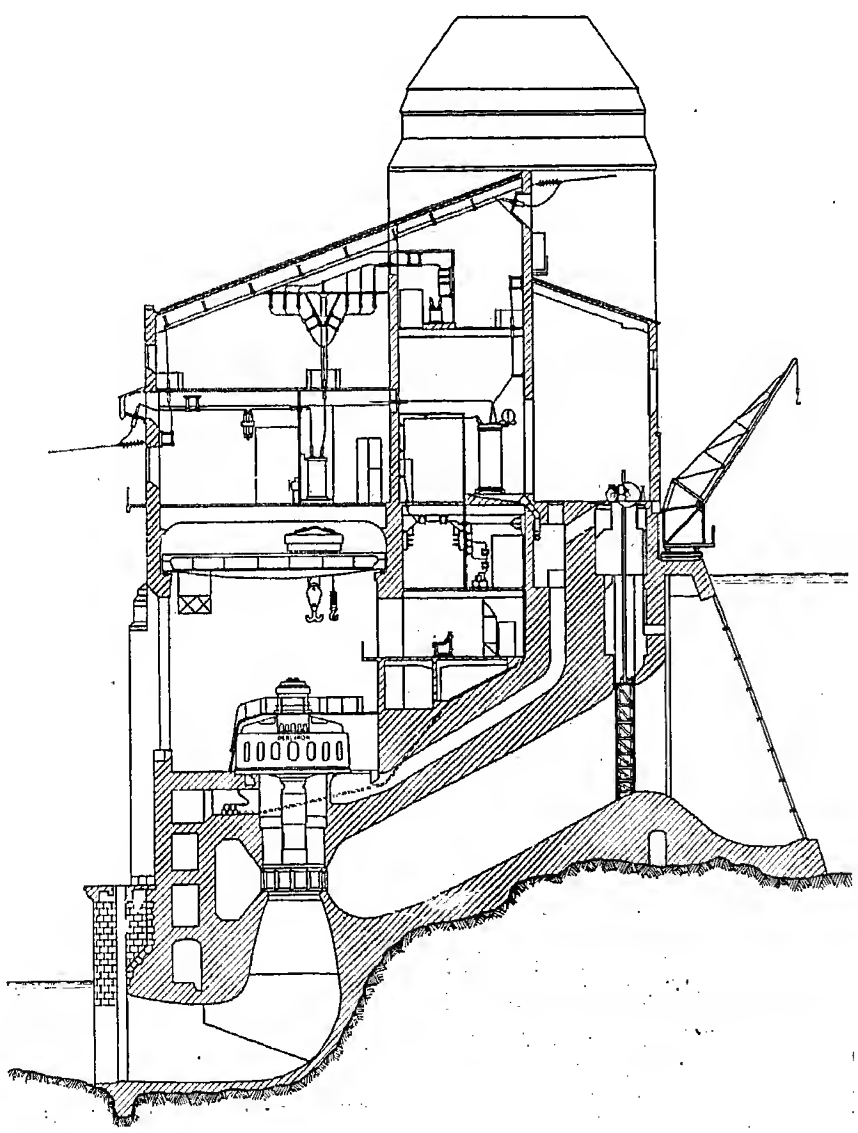
The Mörkfos-Solbergfos installation utilises the water of the Glommen, one of the largest rivers in Norway. The Glommen has its source in the basin of the Aursunden lake, north of Röros; it has a length of about 360 miles and flows into the sea near the town of Fredrikstad. The drainage area of the river amounts to about 15,500 sq. miles.

The installation is situated 58 miles from the mouth of the river and 2½ miles below the Oieren lake which, with its area of 33½ sq. miles, constitutes an excellent regulating reservoir for the power station. In winter, the smallest stream flow to be reckoned with is 52,000 galls/sec, while, in spring, when the snow is melting rapidly, the flow may rise to 660,000 galls/sec. The power is supplied by the three waterfalls of Wittemberg-Halsfredsfos, Solbergfos and Mörkfos, respectively, which represent a total head of 72 ft. in winter and of 52—56 ft. in summer. Once the river is regulated and the full programme of construction completed, the installation will be capable of developing 130,000 HP; the plant will then consist of thirteen 11,000 HP sets, one of these being for standby purposes. The hydraulic works have already been carried out for the full capacity of installation, but the power house itself has, for the present, only been built to accommodate 10 sets. As stated before, all the seven units provided for in the first part of the programme of construction are now in operation. — The main dam is of concrete and measures 370 ft. along the crest. The width is 13 ft. at the top and 98 ft. at the base. The total height from the lowest point to the crest amounts to 160 ft. In order to regulate the flow and the height of storage, provision has been made in the dam for three roller sluices each 65 ft. long. The rollers are carried by toothed wheel segments which engage a rack and can be lowered or raised by means of sprocket chains. Each chain has to deal with a load of 135 tons.

The power house has a width of 137 ft. and a height of 206 ft. measured from base of suction pipe to roof; when the building is completed, it will have a length of 492 ft. (see cross-section below and illustrations on opposite page).

Approximately 4½ million cu. ft. of concrete, with 1500 tons of iron for reinforcing it, were required for this installation, the cost of carrying out the first part of the programme of construction, including interest during building, being Norwegian Krs. 65,000,000. The power station is owned jointly by the City of Oslo and the Norwegian State, in the proportion of 2 to 1.

The whole output, including the share of the State, is, at the present time, taken by the City of Oslo, which has a load rising to 70,000 KW in the winter. The power is transmitted at 60,000 volts by means of five three-phase lines, three with a section of conductors of .147 sq. in. and two with a section of conductors of .108 sq. in., over a distance of 25 miles, to the substation of Töien in Oslo, where the distribution takes place. It may be of interest to mention that Oslo is one of the few large cities in Europe, where electric current is used, on a very extensive scale, for cooking and heating purposes, a development which has been greatly favoured by the low rate charged for current there. In fact, the current is supplied to the householders in the city at a rate of Norwegian Krs. 180.— per KW for the whole year and can be used without restriction for lighting, cooking and heating.



The general arrangement of turbine and generator is shown in the illustration on the next page, which represents a section through one of the sets. The turbine is a low head Francis turbine with a specific speed of 365 rpm. It can develop 11,000 HP, when operating under a head of 69 ft. and at a speed of 150 rpm. The runner is of steel, and cast in one piece; it is fitted with pressed steel vanes. The helical casing at the inlet of turbine, as well as the suction pipe, are made of reinforced concrete, the suction pipe being

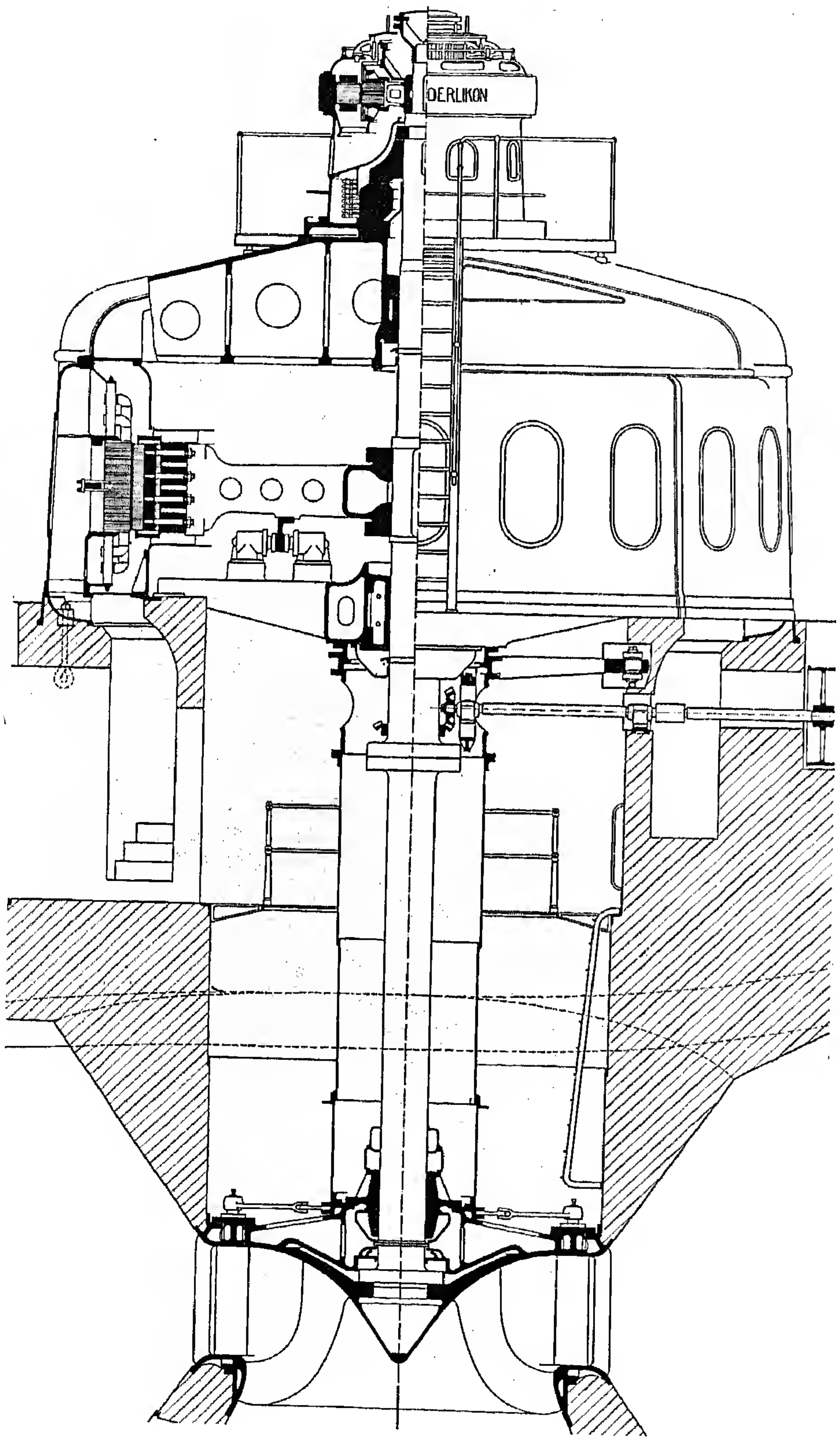
lined with sheet iron. The turbines where manufactured by the two Norwegian turbine makers, Kvärner Brug and Myrens Verksted. The complete generator plant, including exciters, were, as already stated, supplied by the Oerlikon Company. The illustration on the front page shows the machine room, in its present initial state, with all seven units in operation.

The generators are continuously rated and designed to the following particulars:—

Capacity, 10,000–11,000 KVA.
Frequency, 50 cycles.
Pressure, 10,000–11,000 volts.
Number of poles, 40.
Current per phase, 580—605 amps.
Power factor, 0.75.
Speed, 150 r. p. m.
Flywheel effect, 3400 tons at 1 ft. radius.

The shafts of sets are 36 ft. long and subdivided by a flange coupling. Provision has only been made for three guide bearings; the lowest of these bearings is on the turbine and the two upper ones are fitted to the generator. The thrust bearing is arranged on the top of the generator; this bearing has to deal with the whole weight of the rotating parts of generator and turbine, as well as with the thrust due to the water pressure, which represent together a load of 150 tons.

As the portion of generator foundations situated in a transversal direction in relation to the machine room is intersected by the fresh air and warm air channels as well as by the cable ducts, it was advisable to depart from the arrangement with multiple arm support where the heavy weight of the rotating parts would have been evenly distributed over the stator of the generator and the foundations, and to use instead a single yoke disposed in a longitudinal direction, in order to concentrate the weight chiefly on the massive concrete piers between the units. This yoke which is about 23ft. long is of cast iron, and made in one piece; it weighs 20 tons, and is designed for a load of 160 tons (see left-hand illustration on next page).



The stator is in four parts weighing each 14 tons; it rests on a bedplate also made in four parts. The bedplate has four projections to which the lower bearing support is secured; this support is so dimensioned that it can carry the 60-ton rotor, when the latter is lifted on hydraulic jacks for the purpose of dismantling the thrust bearing. The bore of the stator measures 17′ 2$^{11}/_{16}$″; the total width of core is 2′ 7$^{1}/_{2}$″. The stator winding consists of former wound concentric coils placed in open slots. The total number of slots is 240, which corresponds to two slots per pole and phase. Each slot contains five conductors; these conductors are themselves split into four layers, insulated from each other and linked up in such a way as to ensure cyclic permutation, and thus reduce the eddy current losses due to the longitudinal and transversal field in the slots to a minimum value of 35 % of ohmic losses.

The insulation of windings in the slots consists exclusively of heat resisting mica preparation which has the same dielectric strength at all temperatures encountered in the windings.

Each stator coil is dried in a vacuum tank where all traces of air are removed from the insulation; immediately after this operation, the coil is impregnated with compound with a high dielectric strength, which is applied under pressure by means of a process which ensures that the inclusion of air in the coils is, as far as possible, prevented.

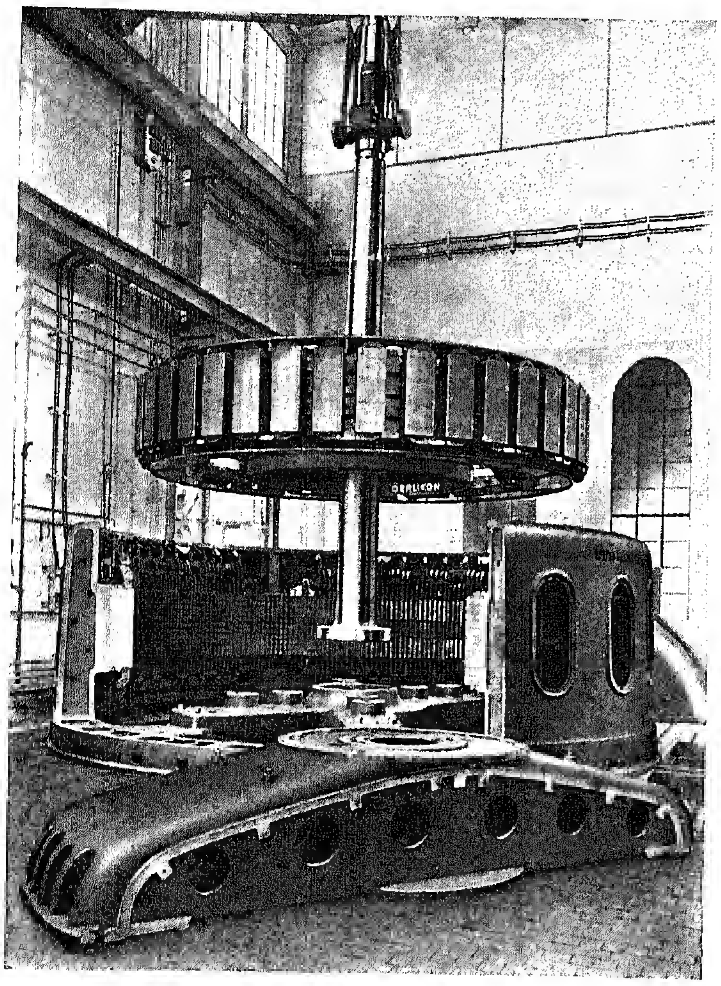
The ends of the stator coils are protected against the effects of electro-dynamic stresses, due to short-circuits in the windings, by special supports. The design of these supports is such that, even at the highest working pressures, there is no possibility of discharges, due to "corona effect" occurring at any point of winding. The right-hand illustration on next page shows four stator quarters complete with winding, ready for despatch. — The 60-ton rotor had to be made in several parts in

order to keep the dimensions within the permissible limits for transport. The rim is built up of four rings of S. M. steel, keyed on a cast iron spider, made in two parts and provided with ten spokes; each ring is made in two halves secured together by means of oval chromium-nickel steel shrunk rings, arranged in milled recesses. In the space between the individual rings, provision has been made for ventilation blades, which permit of the effective cooling of pole coils and stator core, while the fans mounted at either end of the rotor serve to cool the ends of the coils of the stator winding.

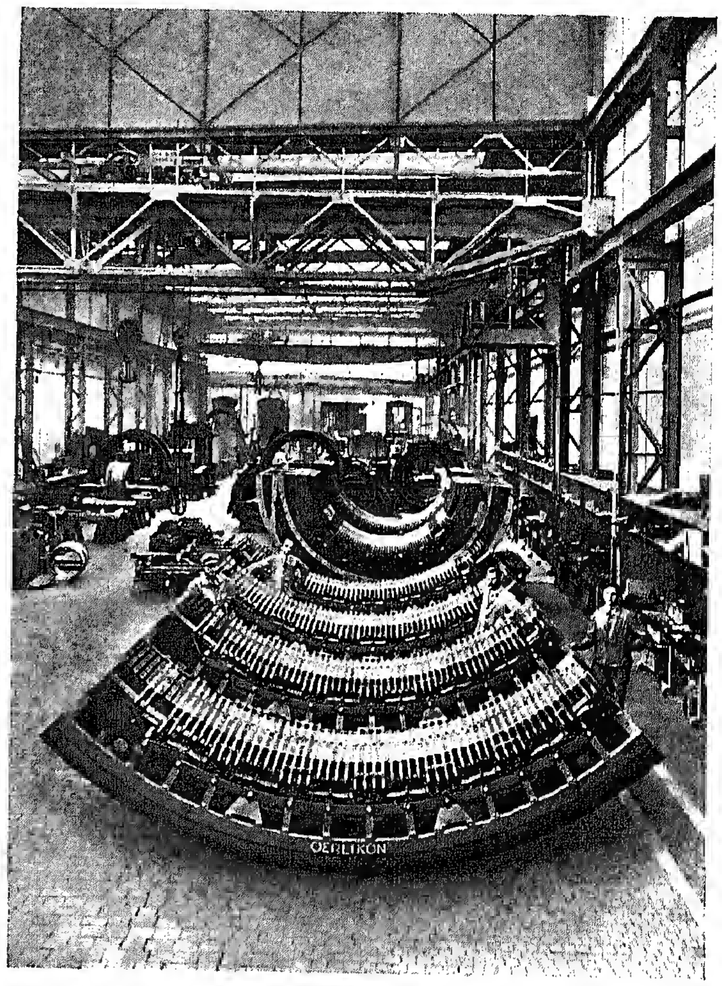
A pneumatic brake is arranged below the rotor between the latter and the lower bearing support; it consists essentially of a brake ring secured to the spokes of the rotor, tric contact which causes the operation of an alarm bell and gives a warning to the attendant, in the event of excessive rise in temperature.

As regards the generators themselves, they are each provided with thermo-couples in four of the stator teeth, with indicators on the switchboard, which give the temperature of iron next to the winding, at any time.

The generators are of the totally enclosed type and self cooled. The fresh air is drawn in from the downstream side, and, after passing through the heat producing parts of the generators, is blown out on the upstream side. The hot air is used, when required, for tempering the air of the sluice chambre and the apparatus rooms.



Parts of generators during assembly in the workshops.



and of four compressed air cylinders with piston, mounted on the bearing support. These brake cylinders are operated by compressed air at 210 lbs. per sq. in. The control valve of the brake cylinders is interlocked in such a way that it can only be operated when the guide vanes of the turbine are completely closed. This brake is mainly intended for bringing the set rapidly to a standstill in the event of defect in the machine, the time required being only 2 to 3 minutes.

The bearing surfaces of the thrust bearings are immersed in oil, which is cooled by water by means of a copper cooling coil. The lubrication and cooling of the guide bearings is ensured by providing an ample circulation of oil, through the use of a geared oil pump, mounted below the generator. The guide bearings as well as the thrust bearing are each fitted with two distance thermometers, one with indicator in the machine room and the other with indicator on the switchboard; each thermometer is provided with an elec-

The exciters are arranged immediately above the thrust bearing; they are built as shunt generators for a maximum continuous output of 94 KW at 240 volts. The pressure regulation of generator is ensured exclusively by varying the excitation of exciter, a quick acting regulator being used for the purpose. The sliprings of the generator are arranged above the exciter; they are made of forged S. M. steel and connected to the field coils of the machine by means of conductors running through the hollow shaft.

The first, second and seventh generator were fully tested at the Works of the Oerlikon Company. The tests of the third, fourth, fifth and sixth generator were, however, confined to the insulation tests of windings and the overspeed tests of completely assembled rotors.

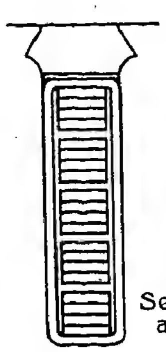
We are giving below a section through a stator slot and also an oscillograph of the generator pressure taken at 10,000 volts, together with the characteristics of the generator, the

loss and efficiency curves, and the characteristics of exciter. The efficiencies were determined by the individual loss method. The values measured exceeded the guarantee figures by 1.5 % at full load and by 3.8 % at half load and power factor .75.

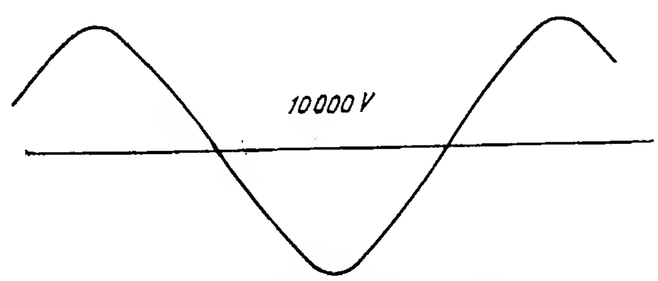
The stator winding after being completely assembled, was subjected to an A. C. test pressure of 30,000 volts at 50 cycles for 15 seconds and, immediately afterwards, to a pressure of 22,000 volts for five minutes. The insulation between the individual turns of the stator coils was tested with a pressure of 11,000 volts applied for 15 seconds. The field coils and the exciter were subjected to a pressure of 2000 volts for a period of 15 seconds, and, immediately afterwards, to a pressure of 1500 volts for five minutes. After the pressure tests, the stator winding was subjected to sudden short-circuits, with the machine running at normal speed and operating at 12,000 volts. During the overspeed trials, the rotor, with its own thrust bearing as support, was subjected to 1.8 times normal speed for five minutes.

It has only been possible to carry out, up to now, in the power station, a full load test on one generator. During this test, the load, pressure and speed were kept as constant as possible for 8 1/2 hours. The maximum temperature rise obtained at the end of the full load run was, in the case of the stator and rotor windings, 10° C below, and in the case of the stator core, 20° C below the guaranteed value of 60° C.

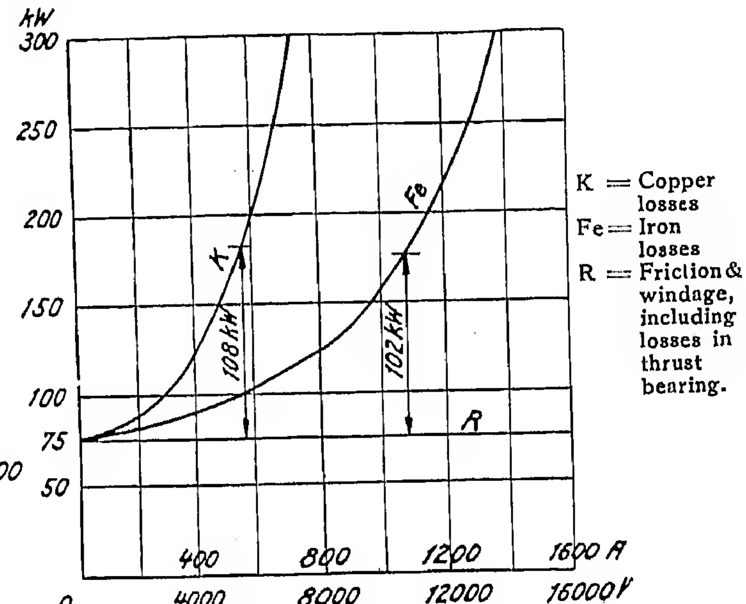
In conclusion, it may be said that the generators have entirely fulfilled all requirements, during continuous service, both in the matter of overload capacity, pressure regulation and parallel operation, as well as in regard to ability to withstand short-circuits. The machines are further characterised by very smooth running and practically noiseless operation from no-load to maximum overload.



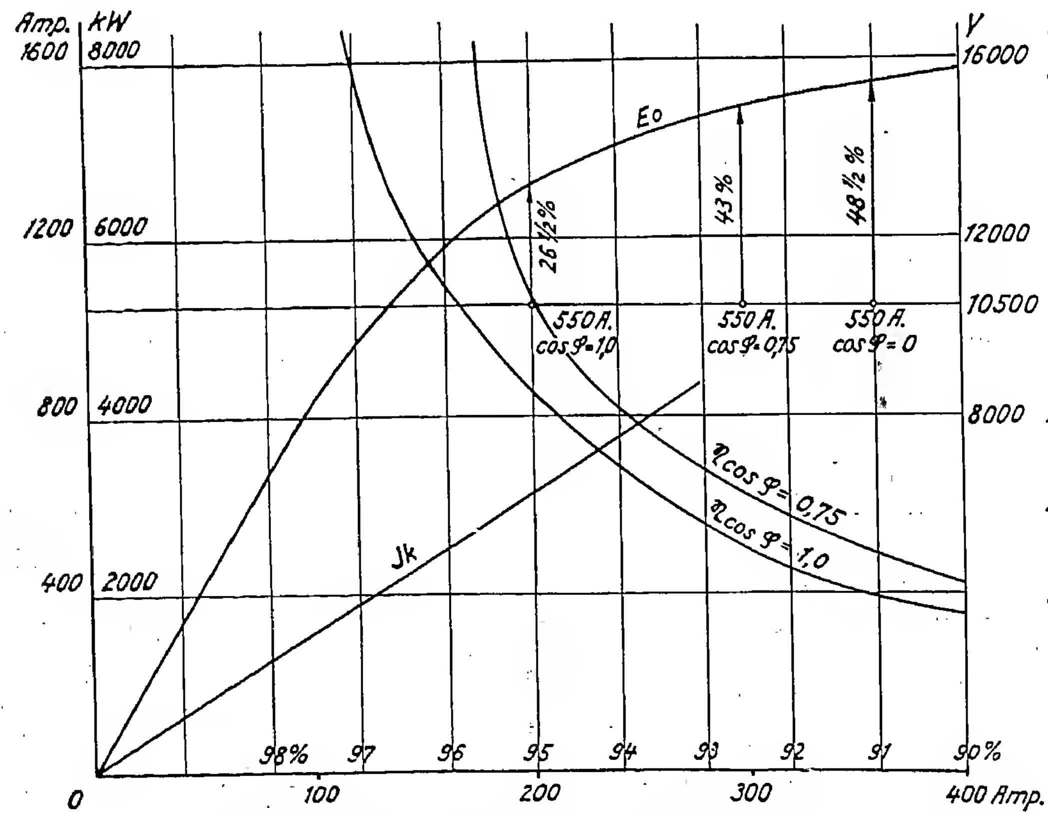
Section through a stator slot.



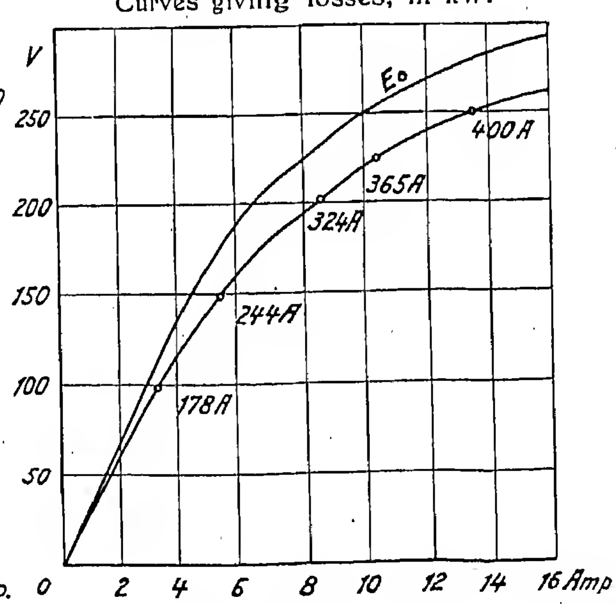
Oscillograph of generator pressure, taken at light load, 10,000 volts, 150 rpm.



Curves giving losses, in kW.



Characteristics of the 10,000 KVA three-phase generator. Excitation

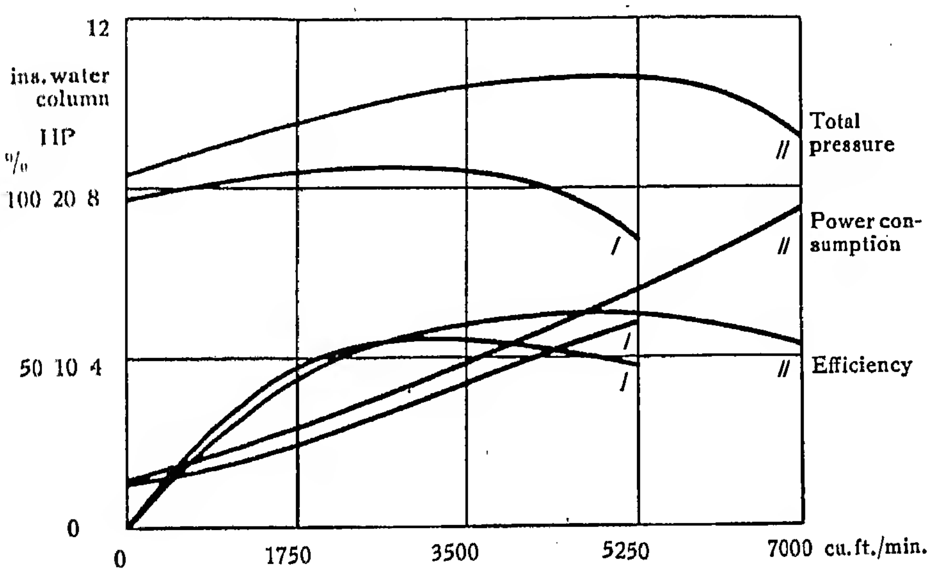


Characteristics of exciter. Excitation

Notes and News Items.

Fans and blowers. It is a well-known fact that fans and blowers, with impellers running at high peripheral speeds, emit, in addition to the usual hum, a whistling note which is, as a rule, very disturbing and may even necessitate the provision of special silencers. The Oerlikon Company have devoted much attention to the matter and succeeded in determining the cause of this phenomenon and preventing its occurrence. The tests they carried out some time ago in this connection have fully confirmed their views as to the origin of the trouble and shown that the whistling was not merely due to the high peripheral

speed but also, and in a greater measure, to the design of impeller. As a result, it was found possible, by taking these factors into consideration, to build an impeller which was quite free from whistling, and practically noiseless in operation, when running at the same peripheral speed and in the same casing as an impeller of the old type. A further advantage derived from this modified design was the increasede delivery obtained. The curves I and II in the chart below represent the performance of the blower before and after alteration. As can be seen, the increase in delivery is quite considerable. An accurate comparison is possible here, as the inlet and outlet angles of impeller where the same in both cases. It must, however, be



pointed out that the curves are not intended to show what are the highest efficiencies obtainable with blowers, but only to indicate what improvement can be secured by altering the design of impeller. In view of the increase in delivery thus attained, a lower peripheral speed can be adopted than with impellers of the old design, for a given quantity of air and pressure, and a further reduction of noise obtained in this way.

Recent developments in the design of tram motors. The use of ventilated motors for tramway purposes has been steadily increasing, ever since experience has shown that modern motors could work in a reliable way, even when full of dirt. Ventilated motors present several advantages in the case of tramcar equipments. The motors can be made smaller and lighter, the diameter of driving wheels, wheel base and unsprung weight can be reduced, while the gear ratio, the motor speed and output can be increased. The conditions are also more favourable for the mechanical part of tramcar and, finally, the specific motor output required is lower.

The Oerlikon Company have, as the result of experience gained during recent years, produced a series of such ventilated traction motors for small outputs. The following are some of the principal features of these machines:—

1) The armature is fitted with a fan, which draws the cooling air, through the openings on the commutator side, past the field coils, over the armature surface, and through the armature core.

2) All windings are insulated in such a way as to ensure reliability in service, even when they are clogged with dirt.

3) The air passages are so arranged as to prevent, as far as possible, the accumulation of dirt and dust, specially in the windings.

4) The armature winding consists of former wound coils carefully designed and very accurately shaped. There are no dummy conductors.

5) The field coils are of moderate thickness, so that no great differences in temperature can occur in the coils.

6) The motors have four identical interpoles.

7) The armature is mounted on a sleeve, so that the shaft can be easily pressed off. Fig. 1 shows a motor of this series.

The cooling effect in this type of motor has been thoroughly investigated in the test room at the Oerlikon Works. On the other hand, in order to ascertain to what extent totally enclosed and ventilated motors differed from each other in the matter of heating during operation, the temperature rise of motors was subsequently calculated for the conditions of service encountered on the three most unfavourable lines of the Zurich tramway system, by making use of the results obtained at these tests. The lines in question were those of Heuried—Allmend Fluntern, Letzigraben—Rehalp and Tiefenbrunnen—Irchelstrasse. The profile of these lines as well as the stopping places and running times are given in Fig. 2. Thanks to the facilities afforded by the Tramway Authorities, it was possible to check these calculations in the case of the Tiefenbrunnen—Irchelstrasse line, by actual measurement during a special run arranged for the purpose.

The calculations refer to motors sizes TM 132 and EM 32c, such as used on these lines, and give the temperature in the warmest part of the machines, i. e., the field winding. The following are the main particulars of the motors:—

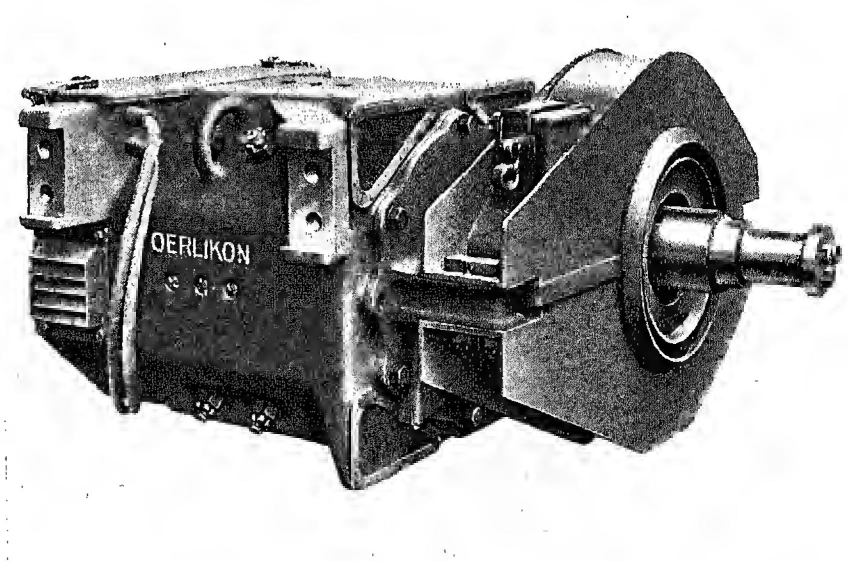


Fig. 1. Self-cooled motor, size EM32c, such as used on the Zurich tramcars.

Motor size	M 132	EM 32c
Design	Totally enclosed	self cooled
One-hour rating at 600 volts	53 KW	48.5 KW
Continuous „ „ 600 „ about	23 KW	34 KW
Motor weight, complete	3000 lbs	2220 lbs

The total train weight was taken as 24 tons. The results of the calculations are given in Fig. 3. As can be seen, the self-cooled motor, owing to its smaller heat capacity, warms up more rapidly; afterwards, however, its temperature remains far below that of the totally enclosed motor.

During the trials on the Tiefenbrunnen—Irchelstrasse line, the temperature readings were taken on a motor, size EM 32c. Four upgrade and three downgrade runs were carried out, with a total train weight of 24.7 tons. There were stoppages of $7^1/_2$ secs., as an average, at 178 of the 203 stopping places.

The temperature rise was determined by measuring the resistance of the field winding.

The temperature readings taken during the tests are represented graphically in Fig. 4, while the curves in Fig. 5 give the maximum temperatures, both measured and calculated, in function of then umber of runs. As can be seen from the latter curves, the measured and calculated values coincide fairly accurately, so that the calculations for the other lines can also be regarded as reliable.

The temperature of commutator was also checked, during a month, every evening, in the tramway sheds, after the return of the tramcars from the Tiefenbrunnen—Irchelstrasse line, the daily mileage being 153 miles; the average temperature rise obtained was 110—125° F for the totally enclosed motors, size TM 132, and 36—50° F for the ventilated motors, size EM 32c. Similar investigations and measurements had already been made some time before on the Uetliberg Railway. The motors in question, which had been in service for a considerable time, were not found to have more dirt in the winding than the totally enclosed machines; it was only at unimportant points of the casing and inside the armature that the accumulation of dirt was greater.

All the results obtained tend to demonstrate the great superiority of ventilated machines. The many possibilities of this type of motor have not yet been exhausted. In the case of ordinary tramway drives, a limit is set to the diameter of driving wheels, by the clearance to be allowed for between gearbox and rails, by the requirements as regards mechanical strength of pinion and by the size of motor imposed by the latter condition. As, however, the value of motor speed is only limited by mechanical considerations, if we disregard the losses depending on the speed, it may be advantageous in many cases to resort to double reduction gears. If bevel gears are then used in conjunction with spur gears, the motor is no longer subjected to any limitation as regards space, such as would otherwise be imposed by the gauge and wheel base. The conditions are in this case more satisfactory both for the gears and motor, and permit of a smaller diameter of driving wheels. This arrangement presents, it is true, the disadvantage of increasing the kinetic energy of the rotating masses, apart from the fact that the drive is more complicated. Experience, however, will show how far economical advantages can be secured in this direction. As regards the detrimental effect of the rotating masses on the drive, this can be easily obviated, mechanically or electrically, by applying the brake directly on the motor shaft.

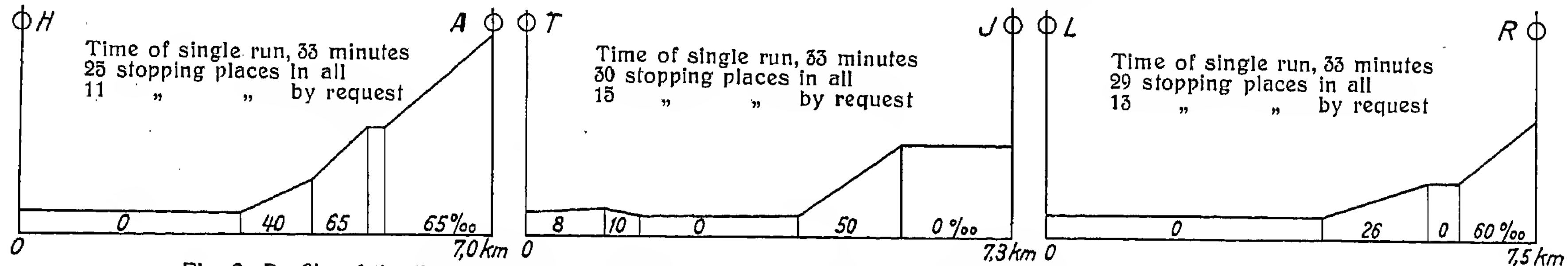


Fig. 2. Profile of the three sections, Heuried—Allmend Fluntern (H—A), Tiefenbrunnen—Irchelstrasse (T—J) and Letzigraben—Rehalp (L—R) of the Zurich tramway system.

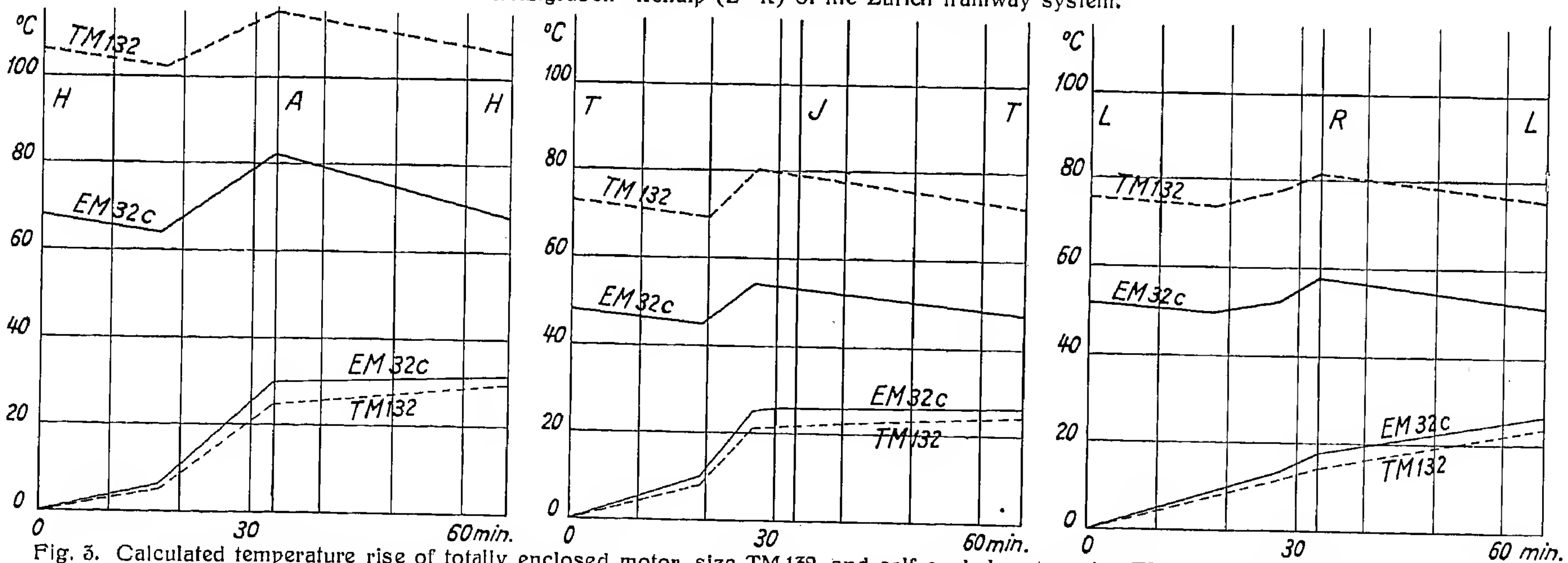


Fig. 3. Calculated temperature rise of totally enclosed motor, size TM 132, and self-cooled motor, size EM 32c, after the first return journey (thin line) and after any number of return journeys (permanent service — thick line), on the three above sections.

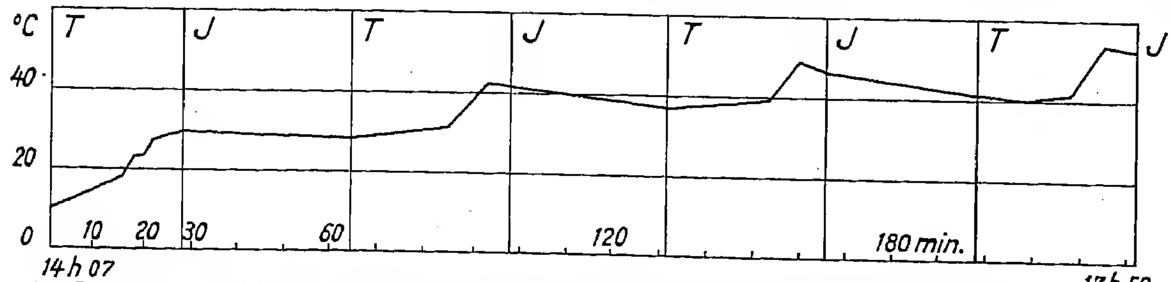


Fig. 4. Calculated temperature rise of the ventilated motor, size EM 32c, after $3^1/_2$ return journeys, on the section Tiefenbrunnen—Irchelstrasse, assuming an outside temperature of 0° C.

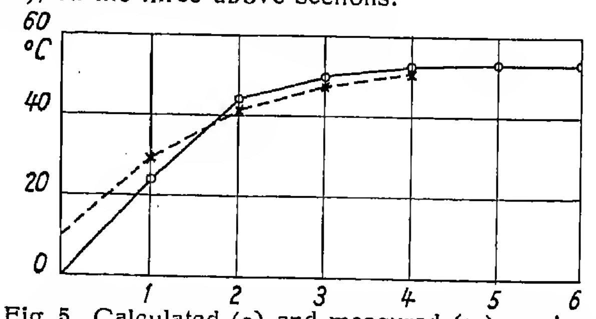


Fig. 5. Calculated (o) and measured (×) maximum temperature rise, after 1, 2, 3, 4, 5 and 6 runs.

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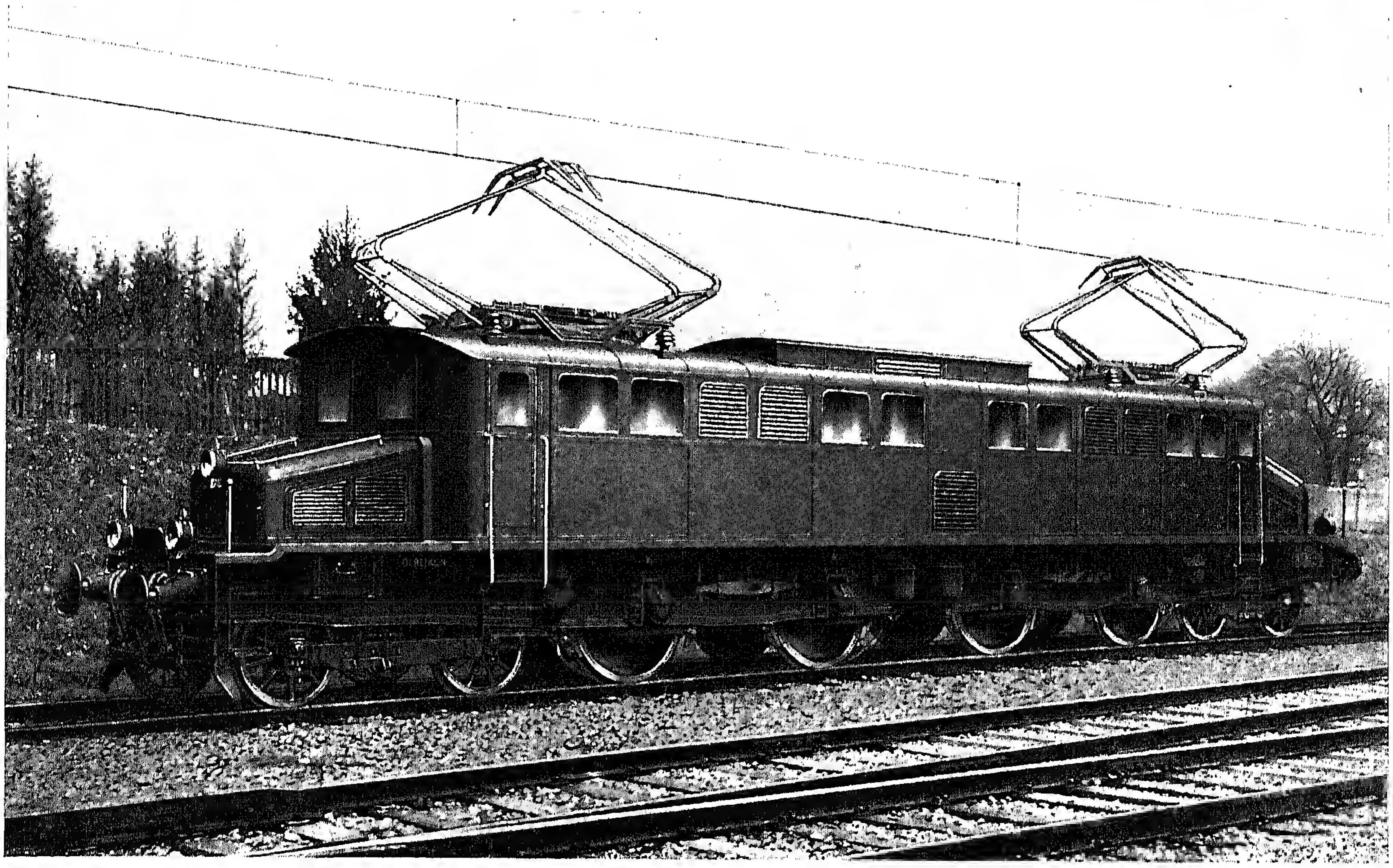


1500 Volt D. C. Express locomotive for the Paris, Lyons and Mediterranean Railway.

After having described in the last issue the new freight locomotives for the Paris-Orléans-Railway, we now propose giving a few particulars regarding the express locomotive for the P. L. M. Railway, which the Société Oerlikon of Paris and the Société de Construction des Batignolles are also supplying.

This locomotive is primarily intended for trial purposes as, in this case, it has been decided to test various types of locomotives before placing final contract. The specification of locomotive was prepared by the Bureau Central d'Etude de Matérial de Chemins de Fer, which has been studying, at the request of the P. L. M. Railway, the electrification of the Culoz-Modane line. The locomotive is to be capable of dealing with gradients having a maximum value of 1 in 33 and curves with a minimum radius of 395 feet. The following are the main data of locomotive:

Speed on gradients of 1 in 33, during 5 minutes:	
with parallel connection of motors	28.5 m. p. h.
with series-parallel do.	13.6 m. p. h.
Normal speed (one hour rating) on gradients of 1 in 67	31 m. p. h.
Normal speed (continuous rating) on gradients of 1 in 20	
with full field of motors	38.5 m. p. h.
with field reduced to 75 %	43.4 m. p. h.
with „ „ „ 50 %	49.6 m. p. h.
Normal speed (continuous rating) on level:	52.8 m. p. h.
Maximum speed on level	68.2 m. p. h.
Tractive effort at wheel rim, during 5 minutes, at 13.6 or 28.5 m. p. h.	41 400 lbs.
Tractive effort at wheel rim (one hour rating), at 31 m. p. h.	28 600 lbs.
Tractive effort at wheel rim (continuous rating), at 43.4 or 49.6 m. p. h.	13 600 lbs.
Tractive effort at wheel rim (continuous rating), at 52.8 m. p. h.	8 800 lbs.
Maximum tractive effort at wheel rim	47 500 lbs.
Output at wheel rim, during 5 minutes, at 28.5 m. p. h.	3 200 HP.
Hourly output at wheel rim, at 31 m. p. h.	2 400 HP.
Continuous output, at wheel rim, at 43.4/49.6 m. p. h.	1600/1840 HP.
Continuous output, at wheel rim, at 52.8 m. p. h.	1250 HP.
Diameter of driving wheels	5 ft. 3 in. (1600 mm)
Length over buffers	65 ft. 7 in. (20 000 mm)
Fixed wheel base of bogies	9 ft. 2 in. (2800 mm)
Wheel base of guiding truck	6 ft. 10 in. (2100 mm)
Total wheel base	55 ft. 9 in. (17 000 mm)

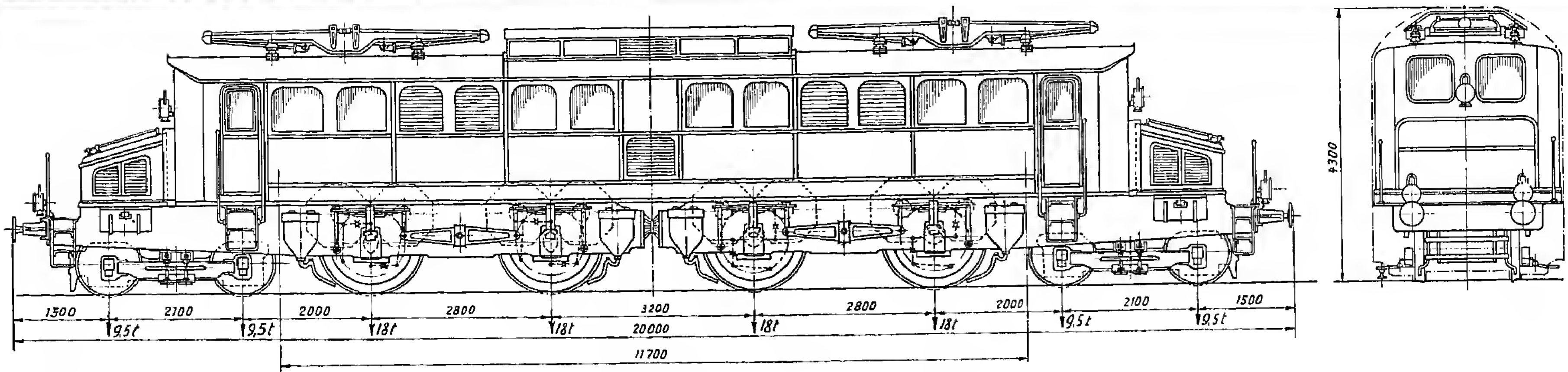


Fig. 2. Outline drawing of locomotive.

Distance between centre pins . . . . 38 ft. 4 in. (11 700 mm)
Total weight . . . . 110 tons.
Weight of electrical equipment . . . . 67 tons.
Weigth of mechanical part . . . . 43 tons.

The coach body of locomotive is carried by two bogies and rests on spherical centre pins and lateral spring borne bearing blocks; each bogie has, in addition to the four driving wheels, a small guiding truck, which supports the extension of bogie frame.

The two bogies are identical. The bogie frame consists of side frames of steel plate with solid cross bracing. The outer extremity of frame is provided with the standard buffer equipment in use on the P. L. M. Railway and is arranged for taking snow ploughs of the special P. L. M. design; the inner extremity is fitted with coupling gear for linking up the two bogies. The bogie frame is spring borne and supported at three points, namely, at the front, on guiding truck and, at the rear, on either side of bogie; the weight applied to the two rear points of support is distributed between the driving wheels by means of laminated springs and equalizing beams.

The design of bogies si similar to that adopted in the case of the bogies of steam locomotives of the P. L. M. Railway.

Individual drive with twin motors is used in the case of each driving axle. The torque of motors is transmitted to wheels by means of axle gears mounted on quill, working in conjunction with flexible coupling; the latter coupling is of a similar design to that adopted by the Oerlikon Company for the new motor coaches of the Burgdorf-Thun Railway *).

*) See Bulletin No. 9, 1922.

The locomotive is provided with driver's cab at either end and apparatus compartment between the two; the driver's cabs are connected by two gangways, running along the sides of apparatus compartment; in view of the position of gangways, it has been possible to arrange them outside the longitudinal girder of underframe, gangway and side of coach body being overhung at bottom of girder. The girders are very solidly built

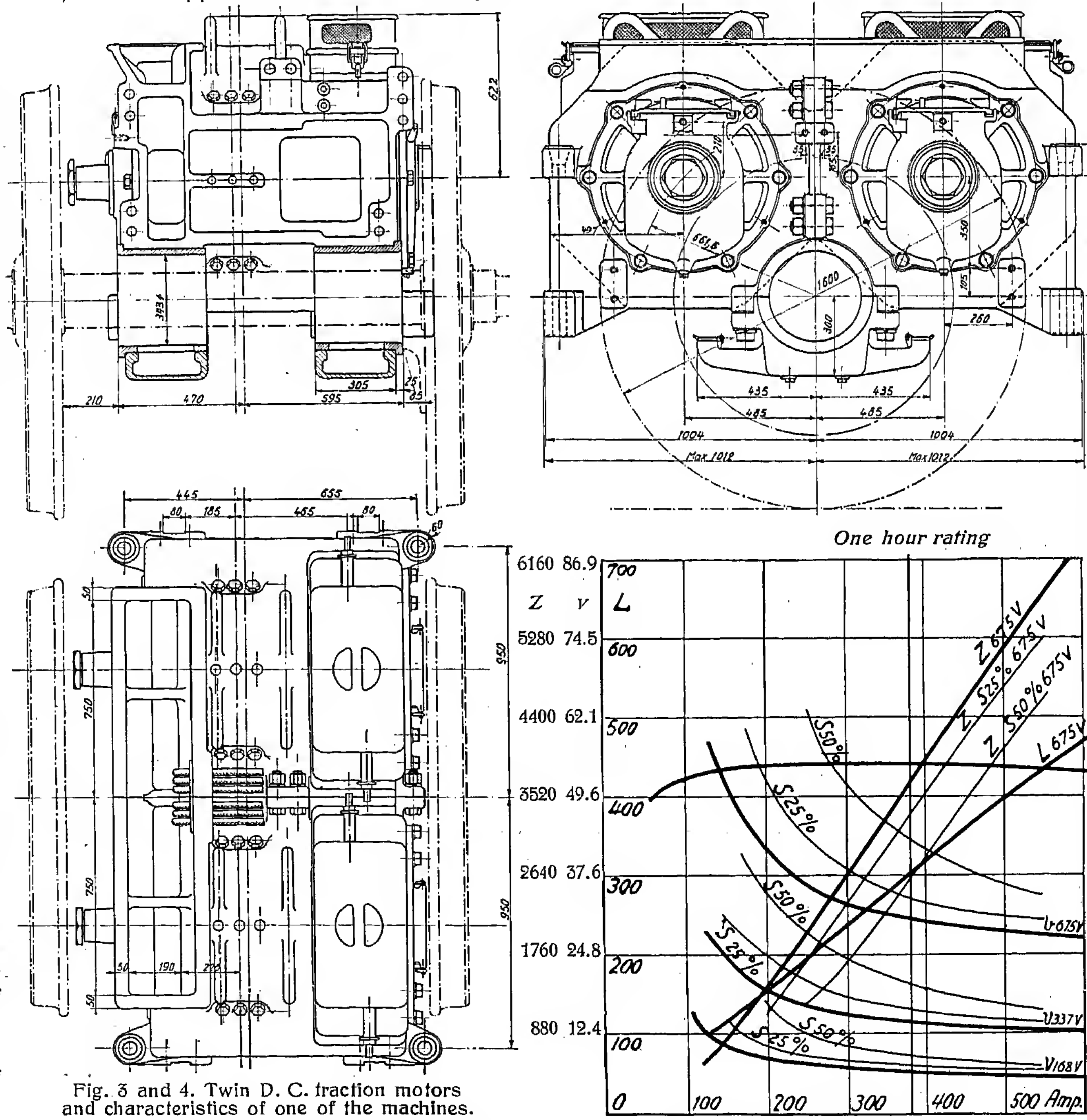


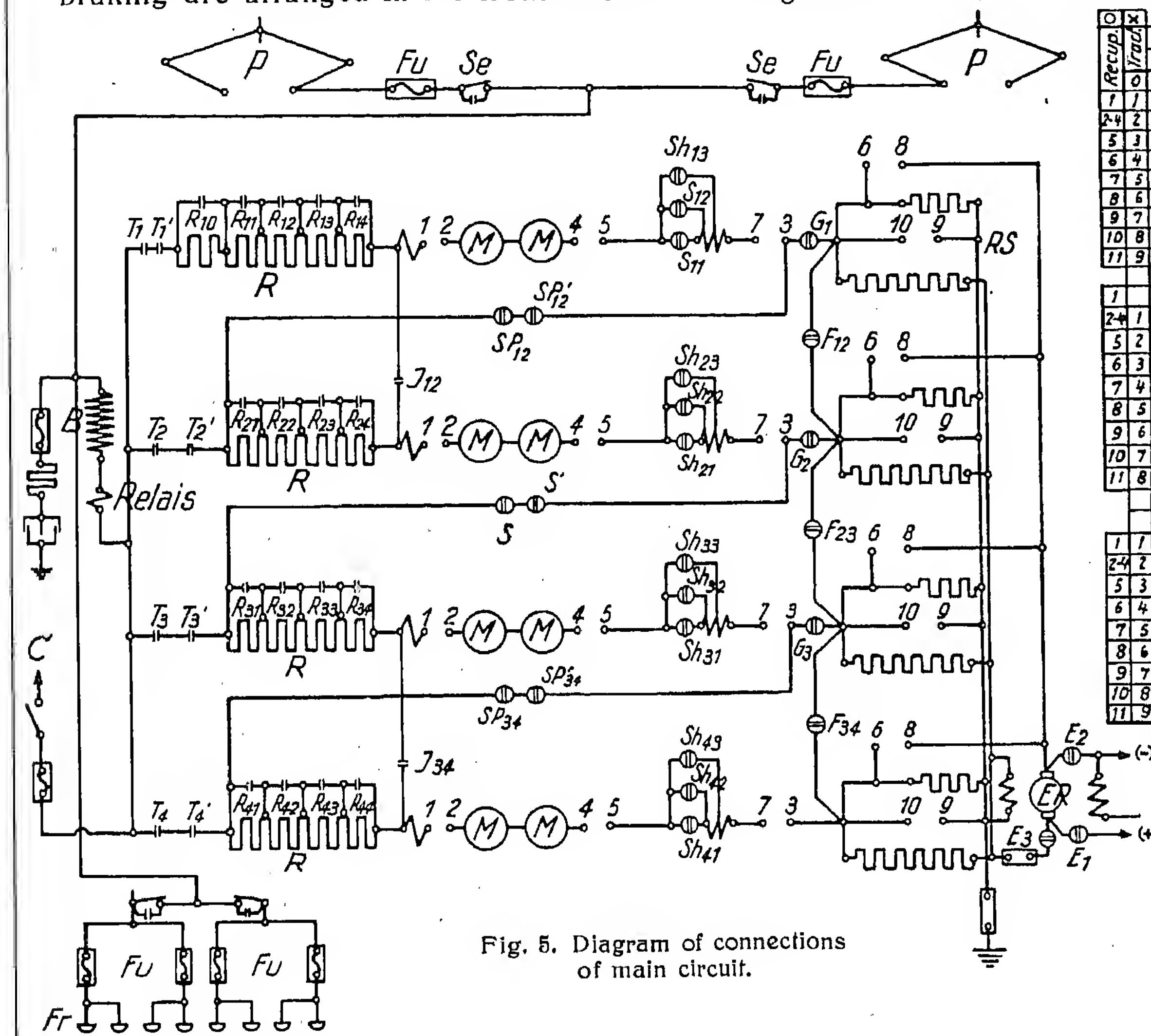
Fig. 3 and 4. Twin D. C. traction motors and characteristics of one of the machines.

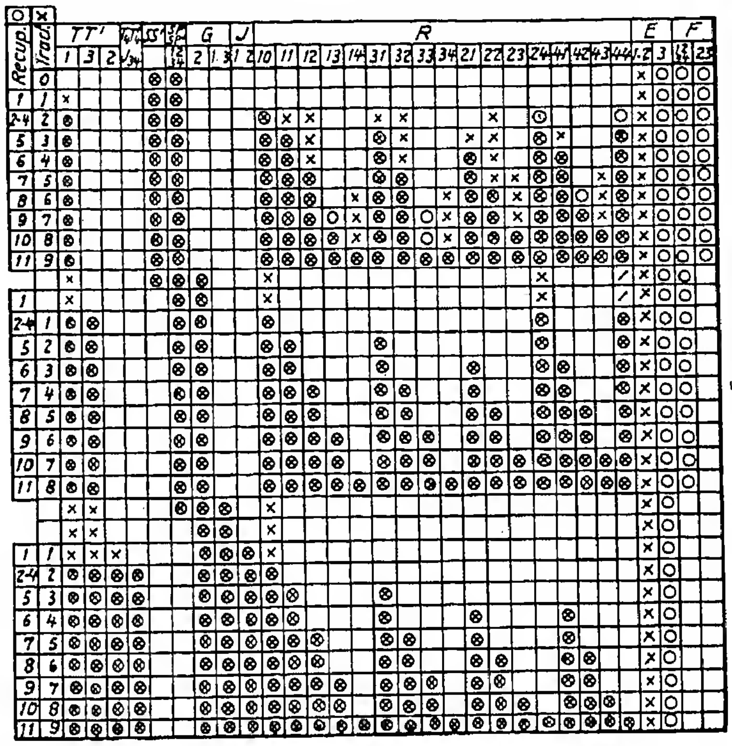
Z = Tractive effort at wheel rim, in lbs.
v = Speed, in miles per hour.
L = Output at wheel rim, in HP.
η = Overall efficiency, in %.

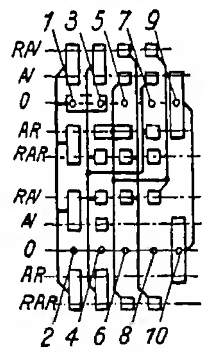
and strongly braced; they carry on their upper part a chequer plate flooring on which is mounted the high tension gear, while the space between girders and below flooring affords ample room for air ducts, cable connections, etc. In order to facilitate erection and dismantling of gear, the whole roof is made in a number of sections which can be removed individually. The resistances are arranged in the raised portion of roof provided above the central part of locomotive and over fan set. The two compressor sets and the motor generator set for regenerative braking are arranged in the front extension of bogie frame.

the control of apparatus, as well as for lighting and for charging the battery of accumulators. The motor driving the set is designed so as to have approximately the same speed at all loads; the exciter, on the other hand, has two windings, one of which is for the excitation of machine and the other for stabilization purposes during regenerative braking.

The locomotive is fitted with two double reversers with five positions, namely, four positions for forward and reverse operation and for regenerative braking in both directions, and one zero position where the corresponding twin motors







Reverser

P Pantograph
Fu Fuse
Se Isolating switch
B Lightning arrester
R Starting resistances
M Motors
Fr Collector shoes
Sh Shunt of field
T, S, SP, G, J, R, E, F Contactors
C Auxiliary circuits
ER Exciter
RS Stabilizing resistances

Fig. 5. Diagram of connections of main circuit.

The locomotive is equipped with automatic and non automatic air brake, with two brake blocks per driving wheel and one per guiding wheel. These brakes are capable of dealing with 75 to 80 % of the weight supported by driving wheels and 55 to 60 % of that carried by guiding wheels. The hand brake is combined with the air brake; it, however, only acts on driving wheels. A signalling equipment with indicator for showing when signals are at danger and a recording speed indicator of the Flaman type are fitted in driver's cab. Reliable sanding for forward and reverse operation is ensured by means of compressed air. The electrical equipment of the locomotive is very similar to that of the goods locomotives of the Paris-Orléans Railway, as the same diagram of connections has been used for main circuit of motors, in both cases; the only essential differences between the two reside in the design of motors and in the fact that regenerative braking is provided here and not on the Paris-Orléans locomotives.

The motor equipment comprises four sets of twin motors, with forced ventilation; each set has a guaranteed hourly rating of 2 × 300 HP. at the normal pressure of 2 × 675 volts, while the output for five minutes, at the same pressure, is 2 × 400 HP. The cooling air is supplied by a fan set of the vertical type; the latter is fitted with two fans, which serve to cool the motors and the resistances, respectively. An exciter set having an output of about 30 KW is provided for exciting the traction motors, when using regenerative braking; this set also supplies the necessary current for

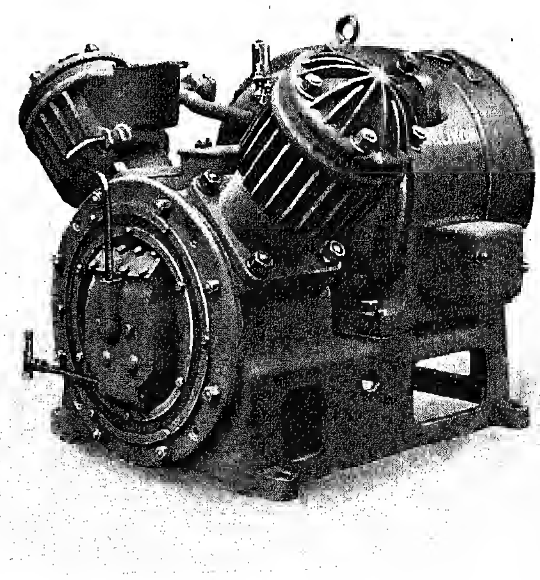


Fig. 6. Air compressor.

are cut out. If one or several motors are out of service the reverser is moved to the zero position; the locomotive can then be started with the other motors in series and operated with these motors only.

The particulars given in the article dealing with the Paris-Orléans locomotives regarding the gear for normal operation of locomotives applies to the present case too. As regards the equipment for regenerative braking, it includes, in addition to the gear already referred to above, the necessary contactor gear for grouping motors and a few additional contactors.

There are still a certain number of features deserving special notice. Mention can be made, for instance, of the fact that the battery of accumulators has a rather large capacity, namely, 200 amp-hours; this high value was adopted in view of regenerative braking. The battery can be charged either by the exciter or by means of the current flowing through the motors of fan and exciter sets. The design of the master controller is also of particular interest; only three handles are used for normal operation and regenerative braking; it is even hoped to reduce this number to two after the trials have been carried out.

In view of the fact that most accidents on locomotives with regenerative braking are due to faulty operation of gear by driver, it is essential to adopt a system as simple as possible so as to eliminate all possibility of error in manipulation. The special Oerlikon controller fitted on the locomotives can be said to satisfy entirely these requirements; the same handle is used both for normal operation and regenerative braking, the changing over from one mode of working to the other being effected by the reverser; regenerative braking can be applied at any speed without fear of the rush of current, due to the connections of motor not corresponding to the speed in question, causing any damage to motor windings; under normal conditions the driver does not have to trouble about excitation of motor as it is regulated automatically.

In spite of these various measures which, under normal conditions, eliminate all danger at time of switching in, it is still necessary to consider the possibility of the line contactors opening during regenerative braking owing to operation of relays for any reason. In order to allow for such a contingency provision had to be made for another means of braking such as would come into play automatically in place of regenerative braking, in case of emergency. At first sight it would have seemed that resistance braking was the solution best suited to meet the conditions; after carefully going into the matter it was, however, realized that, if complications were to be avoided as far as possible, it was essential that the emergency brake should be quite independent of the line pressure and of the rest of apparatus, this being the only way of preventing the automatic operation of brake from being affected by a short circuit or by the breakdown of a motor.

The Oerlikon Company, acting upon the suggestions of the P. L. M. Company, has adopted a very simple solution which consists in the use of the air brake for the purpose in question. The locomotive is thus provided with two automatic features; one of these serves to isolate the brake cylinders of driving wheels, when regenerative braking is resorted to, in order to prevent short circuiting of motors through skidding of wheels; the driver can, however, still use the air brake for the rest of train, should he deem it necessary, for any reason; as soon as regenerative braking ceases the air brake can be applied again to driving wheels of locomotive. The other automatic feature comes into play in the event of failure of regenerative braking; in such a case the air pressure is gradually reduced in brake mains and the driver can then either apply the non-automatic air brake.

The first locomotive of the Paris-Orléans Railway and the locomotive of the P. L. M. Railway are to be put into service in the course of this year. As the trial runs will afford the opportunity of collecting valuable data in connection with these locomotives, we propose supplementing this short description then with information regarding the various questions of special interest.

Length of principal lines.

Paris-Orléans Railway.	
Paris-Vierzon	128.5 miles
Vierzon-Brive	185.5 „
St.Sulpice-Gannat	117 „
Brive-Clermont	167 „
Brive-Montauban	101 „
Other sections	880 „
Total length	1,579 miles
Time allowed for electrification	20 years
P. L. M. Railway.	
Culoz-Modane	84 miles

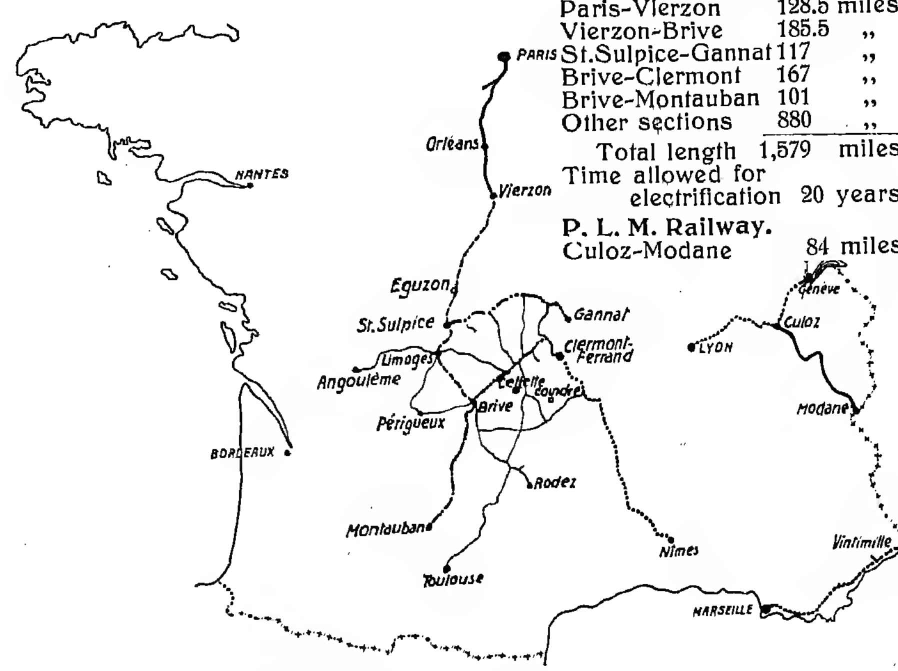


Fig. 7. Map showing lines of the Paris-Orléans and the P. L. M. Railways to be electrified. — The sections already in hand are indicated by thick lines.

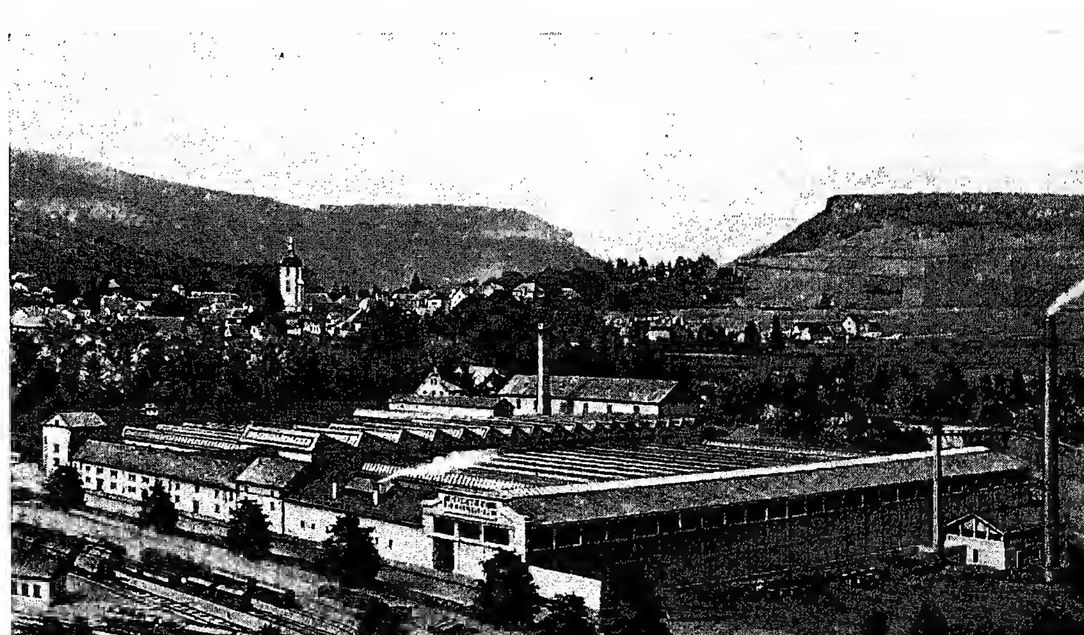


Fig. 8. General view of the works of the Société Oerlikon, at Ornans (Doubs).

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON (Switzerland)

PERIODICAL COMMUNICATIONS OERLIKON

No. 103 — March 1922

Three-Coach Electric Trains of the London & North Western Railway.

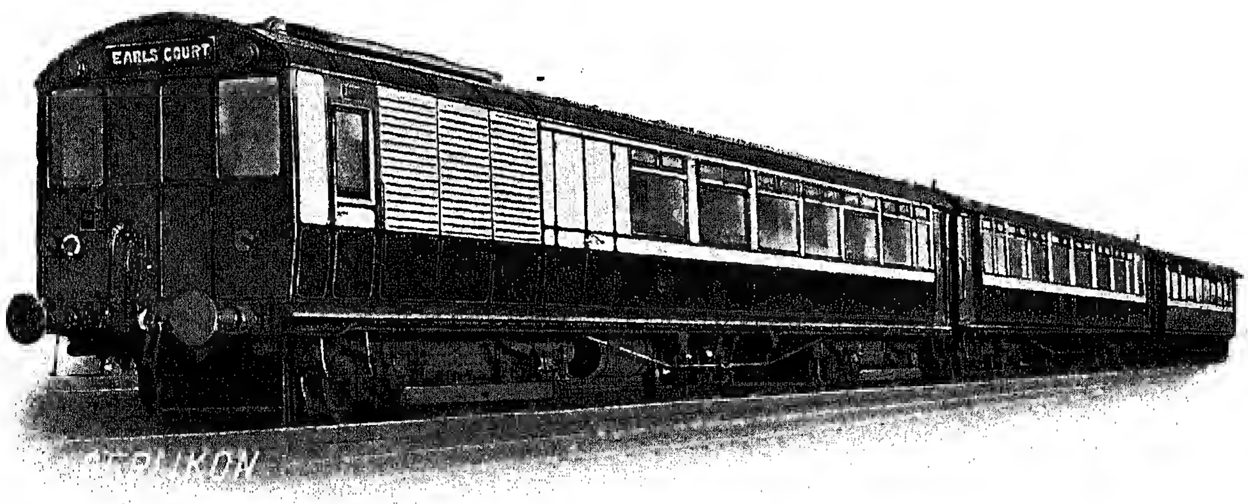


Fig. 1. L. & N. W. Rly Train Unit. 13767
Three-Coach Train, 1000 HP, 630 Volts, current collected from 3rd and 4th rail.

INTRODUCTION.

The Oerlikon Company has not merely devoted its attention, in the matter of Electrification of Normal Gauge Railways, to the single-phase and three-phase systems, but has also in recent years, produced a highly successful design of motor coach equipment for D. C. traction, the motor coaches in question being for the Suburban Service of the London & North Western Railway. The following are a few particulars regarding them:—

Each motor coach is equipped with four motors having each a one hour rating of 250 H. P.; these motors are geared to the axles and suspended in the usual way with rubber compression pads between suspension lugs and the transom. A train speed of 44 m. p. h. can be attained with drawbar pulls reaching 21,000 lbs. Multiple control is provided from any driver cab.

In 1913 the London & North Western Railway Co. placed its first contract for electrically operated Three-Coach Trains for their new Electric Suburban Lines, Euston—Watford, Broad Street—Watford, Broad Street—Kew Bridge and Broad Street—Richmond, Direct Current at 630 volts being chosen as current system.

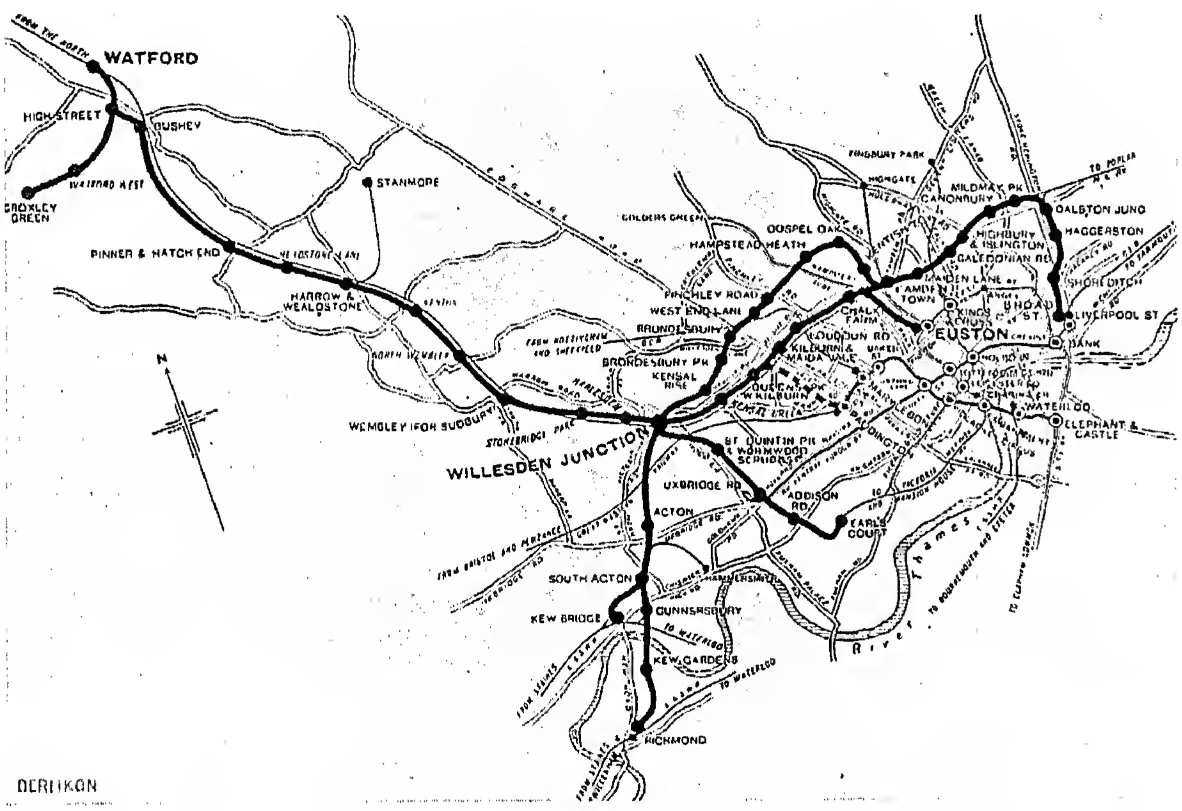


Fig. 2. Map showing electrified System of L. & N. W. Rly and allied Lines. 12957

The underframes, bogies and coach bodies for the 43 motor coaches were manufactured by Messrs The Metropolitan Carriage, Wagon & Finance Co., Ltd., Saltley, Birmingham, whilst those of the 38 trailers and 38 driving trailers were constructed at the Carriage Works of the L. & N. W. Rly at Wolverton.

The electrical equipments for these coaches were ordered from the Oerlikon Company, an additional order being placed with them in 1915 for the electrical equipments of a further 30 Three-Coach Trains and 3 spare motor coaches. These two contracts, covering in all 76 motor coaches, 68 trailers and 68 driving trailers, were executed under very difficult conditions, as manufacture and erection were carried out, to a great extent, during the War.

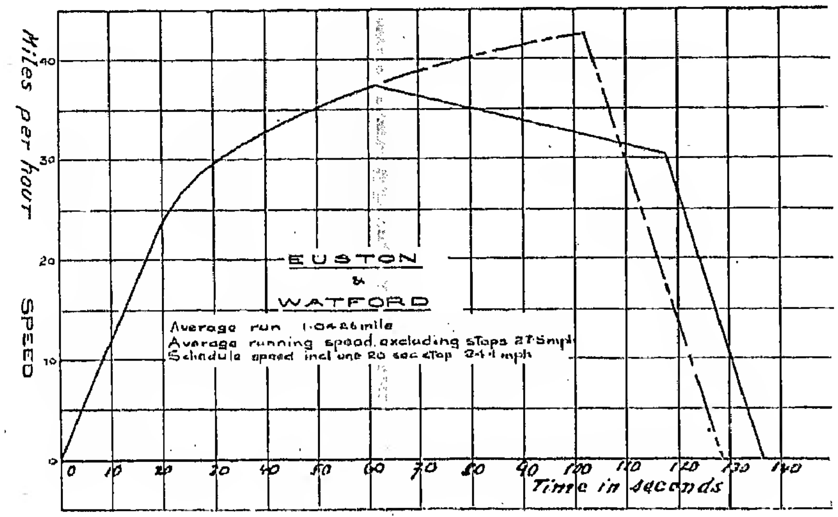


Fig. 3. Starting diagram (Euston and Watford). 17050

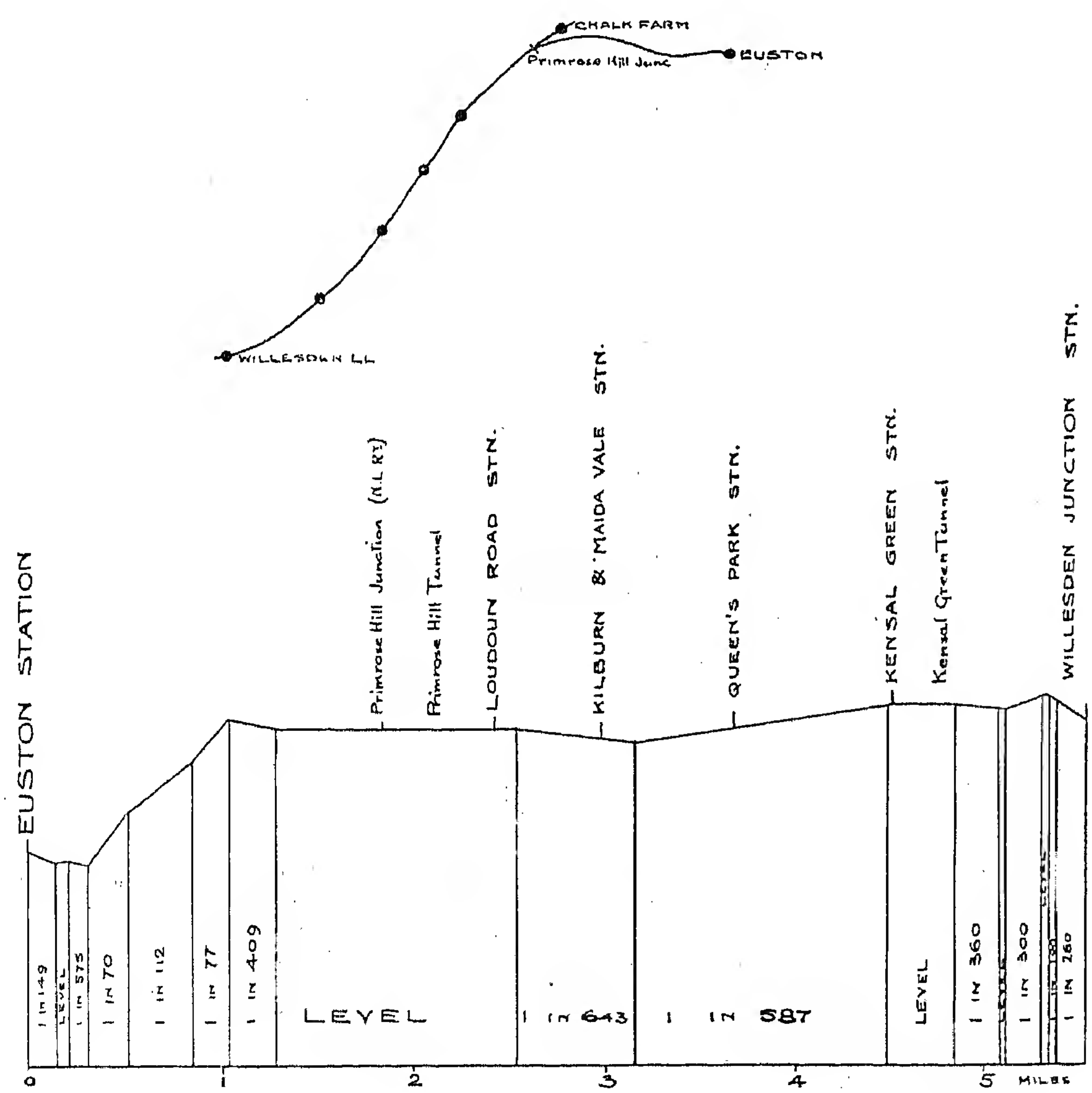


Fig. 4. Profile of section Euston Station—Willesden Junction, with plan. 17051

Owing to the many conditions imposed by heavy suburban traffic, it was necessary to go into the whole question of electrical equipment very thoroughly. In the case of motor as well as of apparatus, special design had to be adopted, which, in many ways, departed considerably from standard practice; all these modifications proved however entirely satisfactory. It can also be added that the Oerlikon Company evolved and patented a new system of multiple control for these coaches.

From the year 1915 onwards, the Three-Coach Train units under the first contract were put into service, and gave excellent results. Due to the exigencies of the War, the manufacture of the underframes, bogies, etc. and the coach bodies under the second contract had to be suspended until the end of the War: the material under this contract has now been delivered and stored at Saltley and Wolverton, and the equipments are in the course of erection.

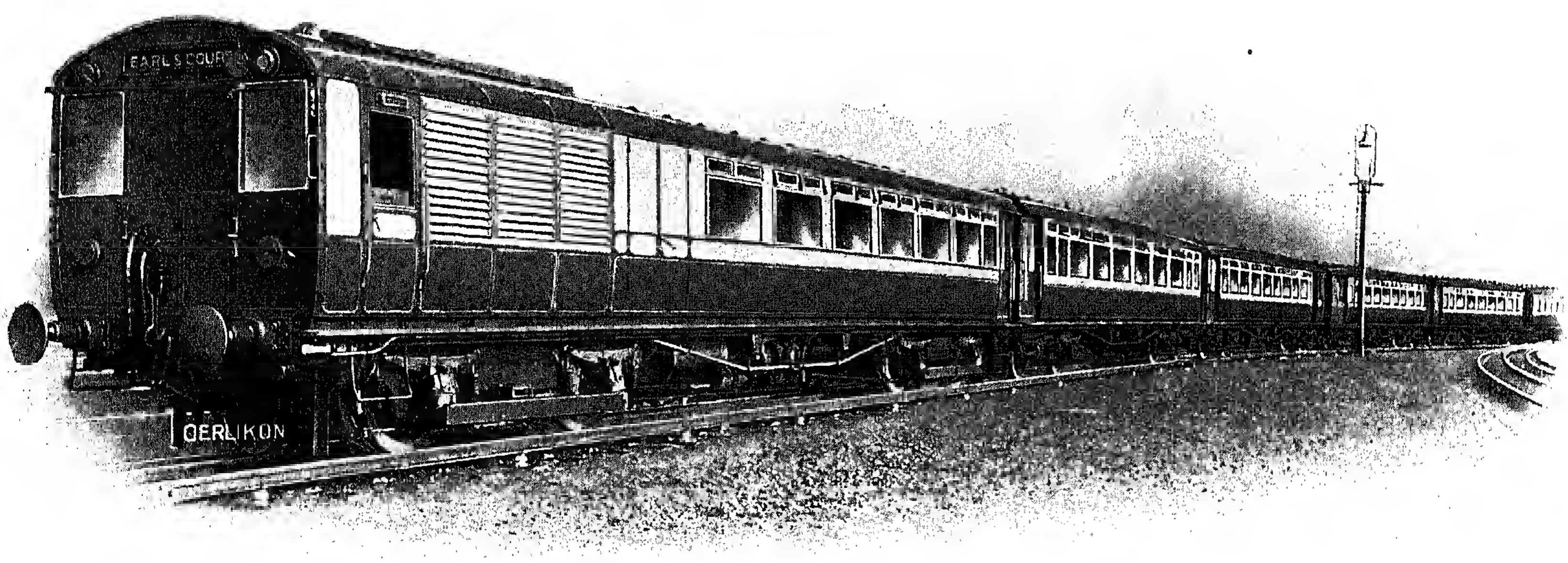


Fig. 5. Six-Coach Train of L. & N. W. Rly. 14598

The following is a brief summary of the very exhaustive and complete specification issued by Lieut-Colonel F. A. Cortez-Leigh, T. D. R. E., the Chief Electrical Engineer of the London & North Western Railway: -

The traffic unit is a Three-Coach Train consisting of a motor coach with apparatus compartment and driver's cab, a trailer coach without driver's cab, and a driving trailer coach with driver's cab. These must be so arranged that two such Three-Coach Trains can be coupled together and operated by means of multiple control. The multiple control is to be non-automatic as well as automatic, i. e. the driver is to be able, at will, to operate the controller for all the starting notches or to put the controller handle immediately on to the requisite running position; the whole starting process is, in the latter case, to be governed by a relay, which operates when the motor current drops to a pre-

determined value after each successive current rush, and thus controls the automatic notching up. Furthermore, the electrical equipment of the Three-Coach Train is to be arranged in two completely independent halves, so that one or the other half can easily be cut out when desired. Each motor coach is to be provided with 4 motors, 2 motors being mounted on each bogie.

To determine the capacity of motors, calculations were based upon the profile of the various lines to be electrified and the speed diagrams for the different gradients. The

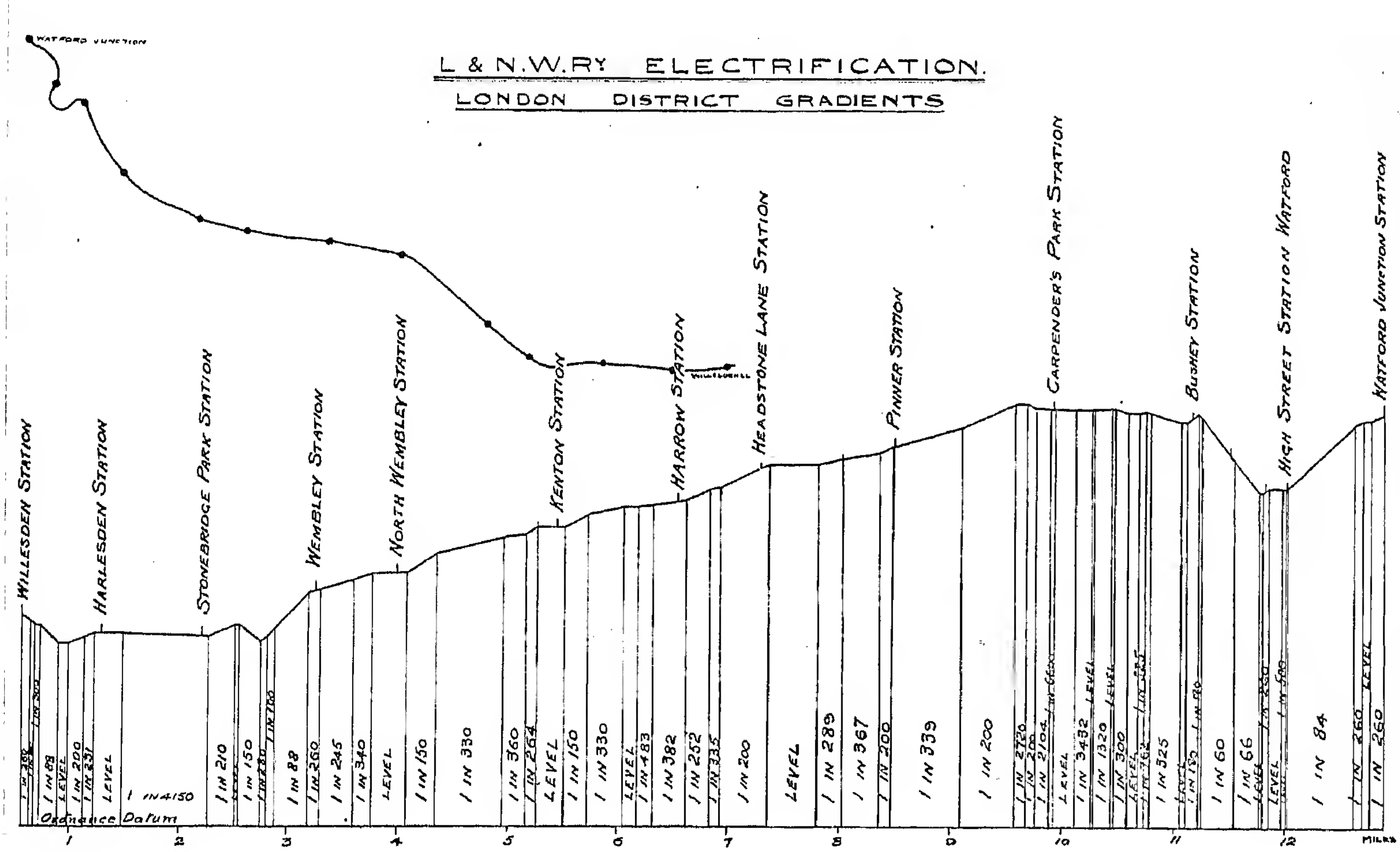


Fig. 6. Profile of section Willesden Station—Watford Junction Station, with plan. 17052

estimated weight of each train was 112 tons, including 12 tons for passenger load and 16 tons for electrical equipment. It was however necessary when fixing capacity of motors to take into account the fact that the weight of electrical equipment might exceed the value assumed. After completion, it was found that the weight of train and equipment, exclusive of passengers, amounted to 112 tons.

The figure obtained from calculations for one hour rating of motors was 225 H. P. measured at wheel rim. The motors supplied, are however capable of developing 250 H. P. at wheel rim, on one hour service.

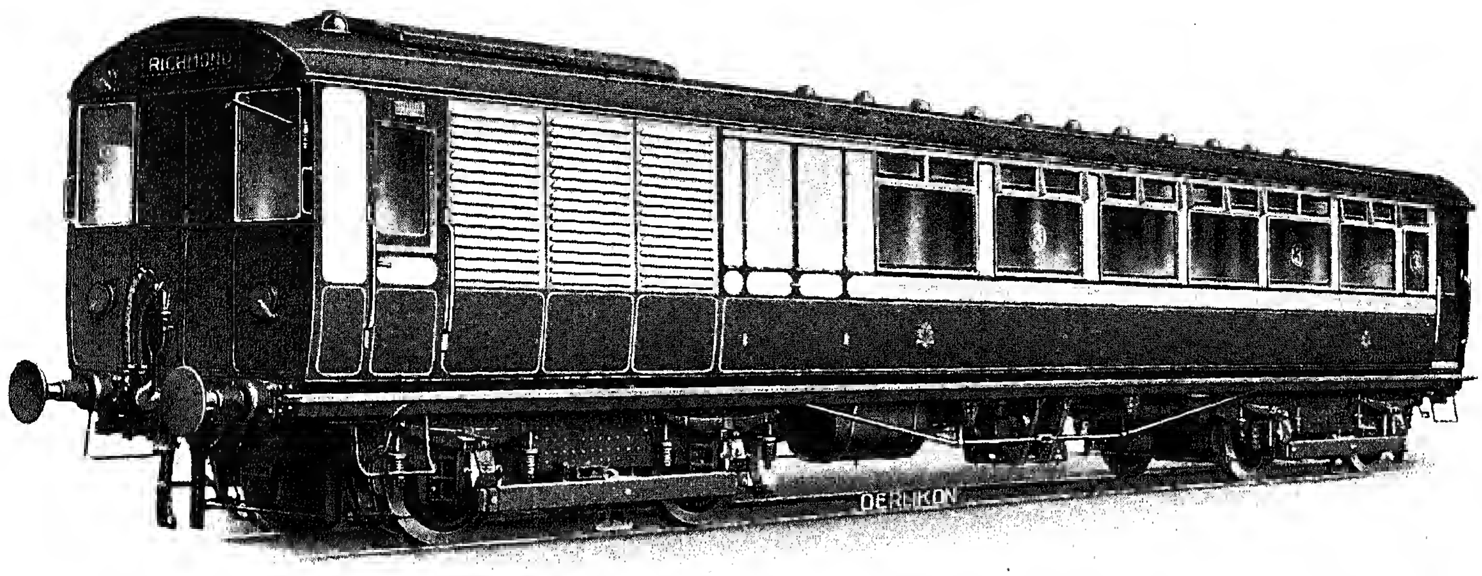


Fig. 7. Motor Coach of Three-Coach Train with one hour rating of 1000 HP. 13765

The principal data of the complete Three-Coach Trains are as follows:

Average running speed	25 m. p. h. (40 km p. h.)
Maximum „ „	about 40 m. p. h. (70 km p. h.)
One hour rating measured at wheel rim	1000 H. P.
Drawbar pull „ „ „	14000 lbs (6360 Kgs.)
Maximum drawbar pull	21000 lbs (9550 Kgs.)
Average acceleration when starting	1.2 m. p. h. per sec (0.535 metres per sec, per sec)
Average pressure	575 volts
Gauge	4' $8^1/_2$" (1435 mm)
Diameter of driving wheel	3' $7^5/_8$" (1108 mm)
Weight of Three Coach Train (empty)	112 tons (113,792 Kgs.)

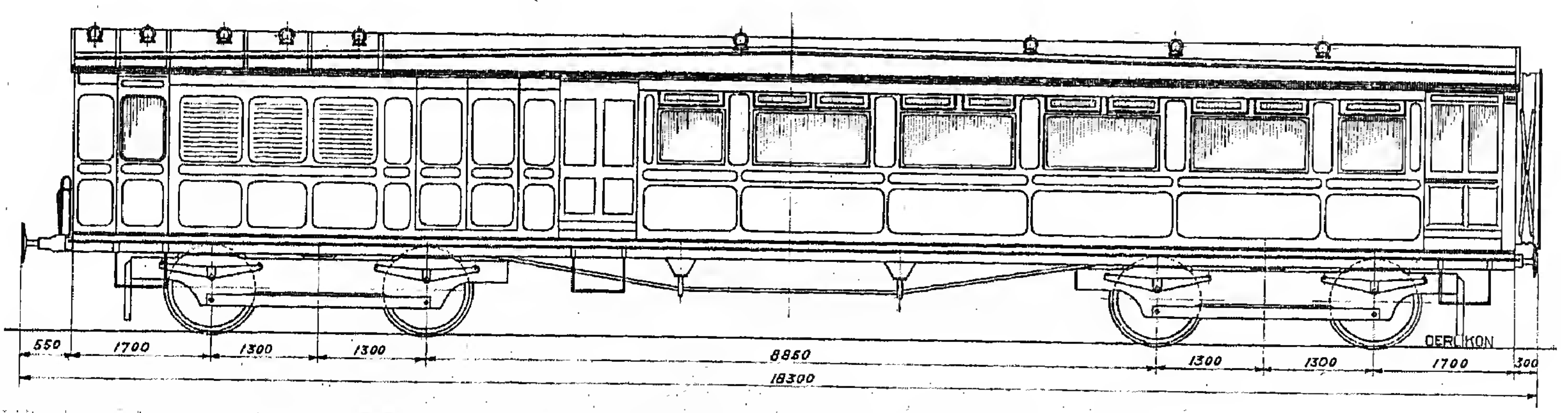


Fig. 8. Outline drawing of Motor Coach. 17054

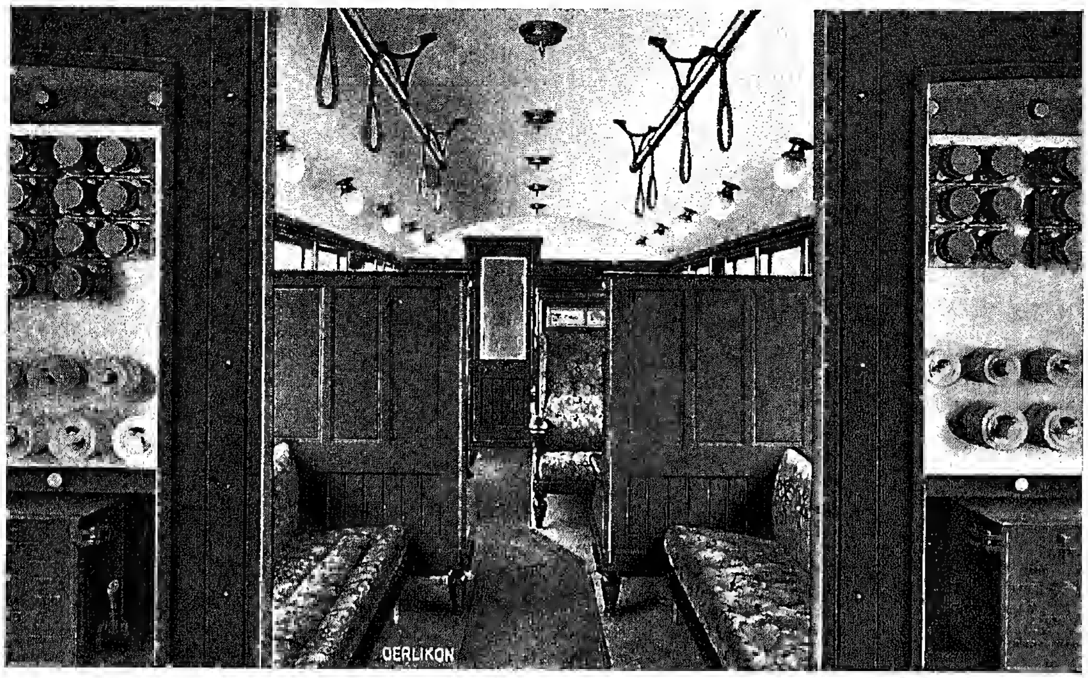


Fig. 9. First class Compartment in Trailer. 13506

Mechanical part . . . . 92 tons (93,472 Kgs.)

Electrical part consisting of:

Motors	Switchboard
Contactors	Contact Shoes
Circuit Breakers	Controllers
Reversers	Main Fuses
Starting Resistances	Lighting and Heating equipments
Couplers and Sockets	Cables, Conduit and various erection material
Relays	

Approximately . . . . 19,7 tons (20,000 Kgs.)

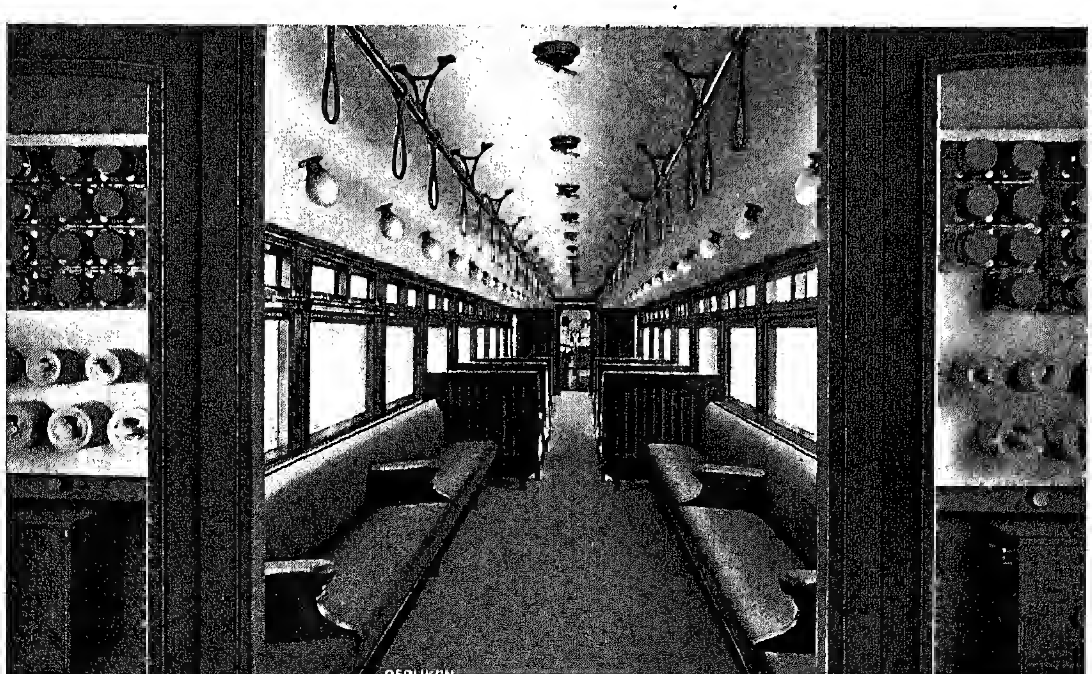


Fig. 10. Third class Compartment in Driving Trailer. 13505

MECHANICAL PART.

The motor coach is provided with 2 two-axle bogies and a driver's cab at one end only; adjoining the latter is the apparatus cabin, the sides of which are provided with louvres for ventilation purposes. A small luggage compartment is arranged between the passenger compartment and the apparatus cabin, doors being provided to enable the train staff to pass right through the train. The trailer, without driver's cab, is also mounted on 2 two-axle bogies and has one third-class and two first-class compartments; the interior of coaches is carefully finished off, and the space conditions are very ample. The driving trailer, with driver's cab, is at the end of the Three-Coach Train; it is carried, as in the case of the other coaches, by 2 two-axle bogies. This coach is wholly reserved for third-class passengers, and constitutes one large compartment.

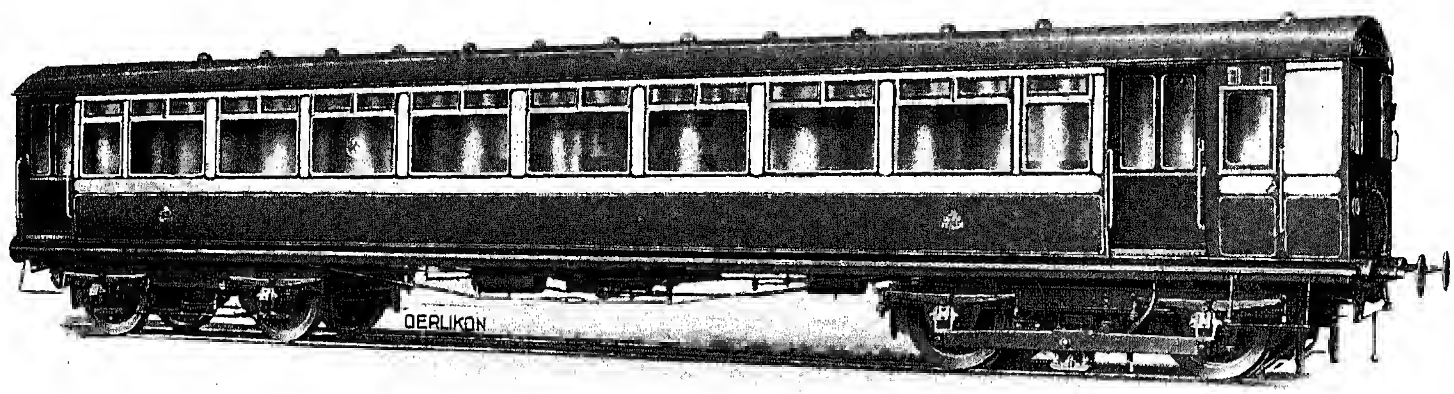


Fig. 11. Driving Trailer with Driver's Cab. 13492

The seating accomodation in all compartments of the Three-Coach Train is arranged both lengthways and transversely. All coaches are fitted with standard Westinghouse air brakes, motor coaches and driving trailers being provided with hand brake as well.

The lighting and heating of the coaches is electric throughout, and the current for same is taken and mainly controlled from the motor coach. Small marble switch panels are fitted in each car vestibule, whereby any series of 5 lamps or set of heaters can be turned on or off. Two single-pole switches are fitted in the luggage compartment of the motor coach, each controlling half the lighting and heating of the Three-Coach Train, so that the guard can turn on or off the whole train lighting from one position, provided the local switches mentioned above are on. A single pole switch is also fitted in the vestibule of each driving trailer coach, so that the guard can control half the lighting from that end of the train. when necessary.

2 Three-Coach Trains can be coupled together so as to form one train and controlled jointly from one driver's cab, if traffic requirements necessitate this. When this train composition is adopted, the motor coaches are usually coupled at the extreme ends of the train.

ELECTRICAL EQUIPMENT.

The whole electrical apparatus is fitted on motor coach. The diagram of connections given here refers to motor coach equipment only; furthermore, lighting, heating and air compressor, are not shown on it. The middle coach, or trailer, merely carries the busline cables for the main current, the control leads and the cables for compressor, lighting and heating; all these connections are run through the underframe of the coach. The motor and the driving trailer coaches at the ends of the train are fitted with complete control equipments. The third and fourth rail system has been adopted for collecting

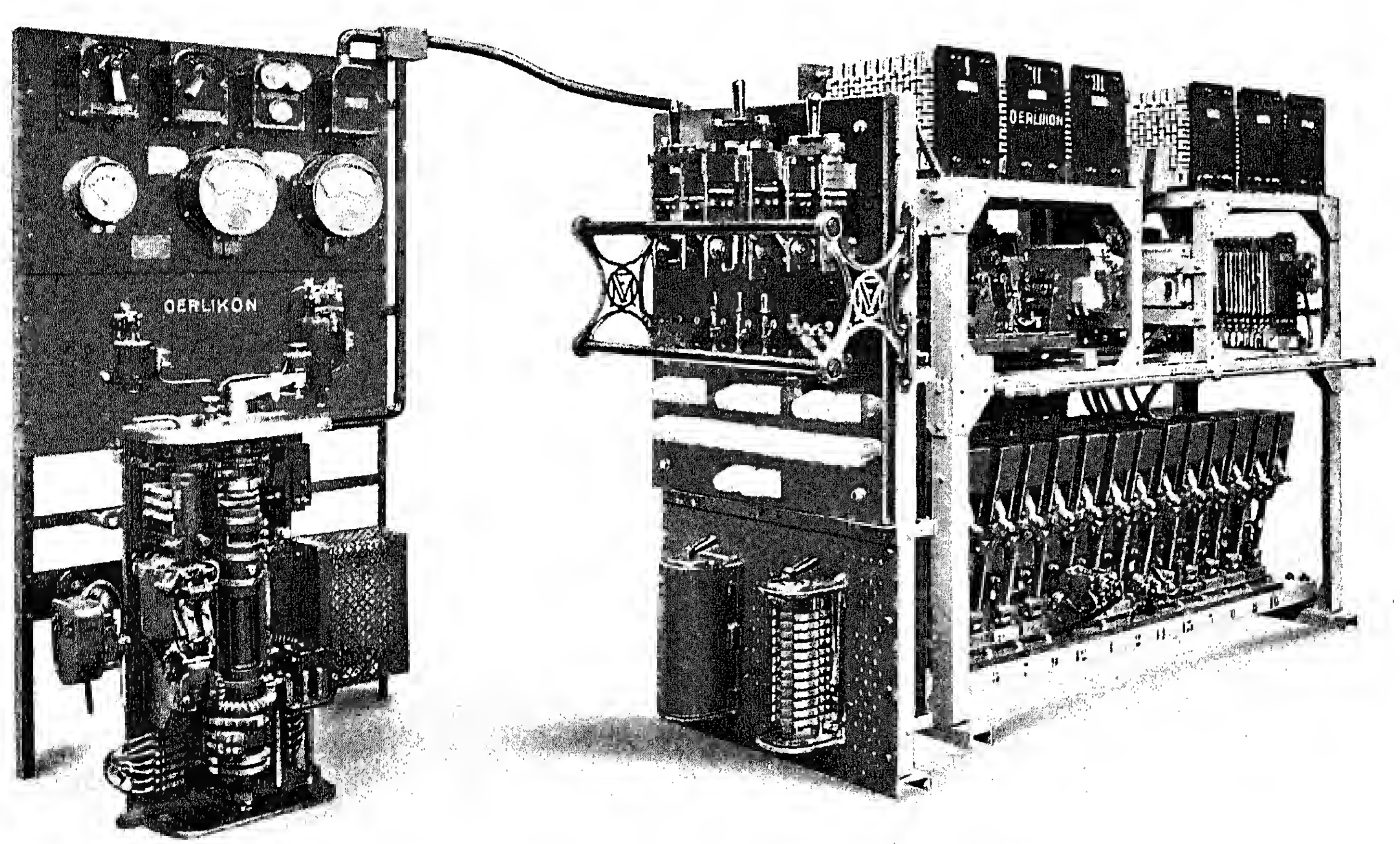


Fig. 12. Control Equipment erected in test room. 12805

the current. The negative contact rail is arranged in the centre between the running rails, and the positive contact rail is placed outside the track with its centre 16 inches from gauge line; the current is collected from positive rail by means of sliding contact shoes, pressed down on rail by their own weight and suspended from cast steel brackets; these brackets are bolted to oak shoe beams, carried on the axle boxes of the bogies. The contact shoes on the driving trailers are suspended from brackets in a similar way; these brackets are also supported by oak shoe beams. The negative shoe on motor coaches is carried by a short oak beam fixed to a bracket attached to the motor casing. Both

bogies on the motor coach, as well as the end bogie of the driving trailer (immediately beneath the driver's cab) are fitted with contact shoes. All contact shoes are connected to the main busline cables, and are individually protected by contact shoe fuses. The main cables are connected to the main knife switch on the switchboard in the driver's cab, so that the whole electrical equipment can be isolated by means of this main switch.

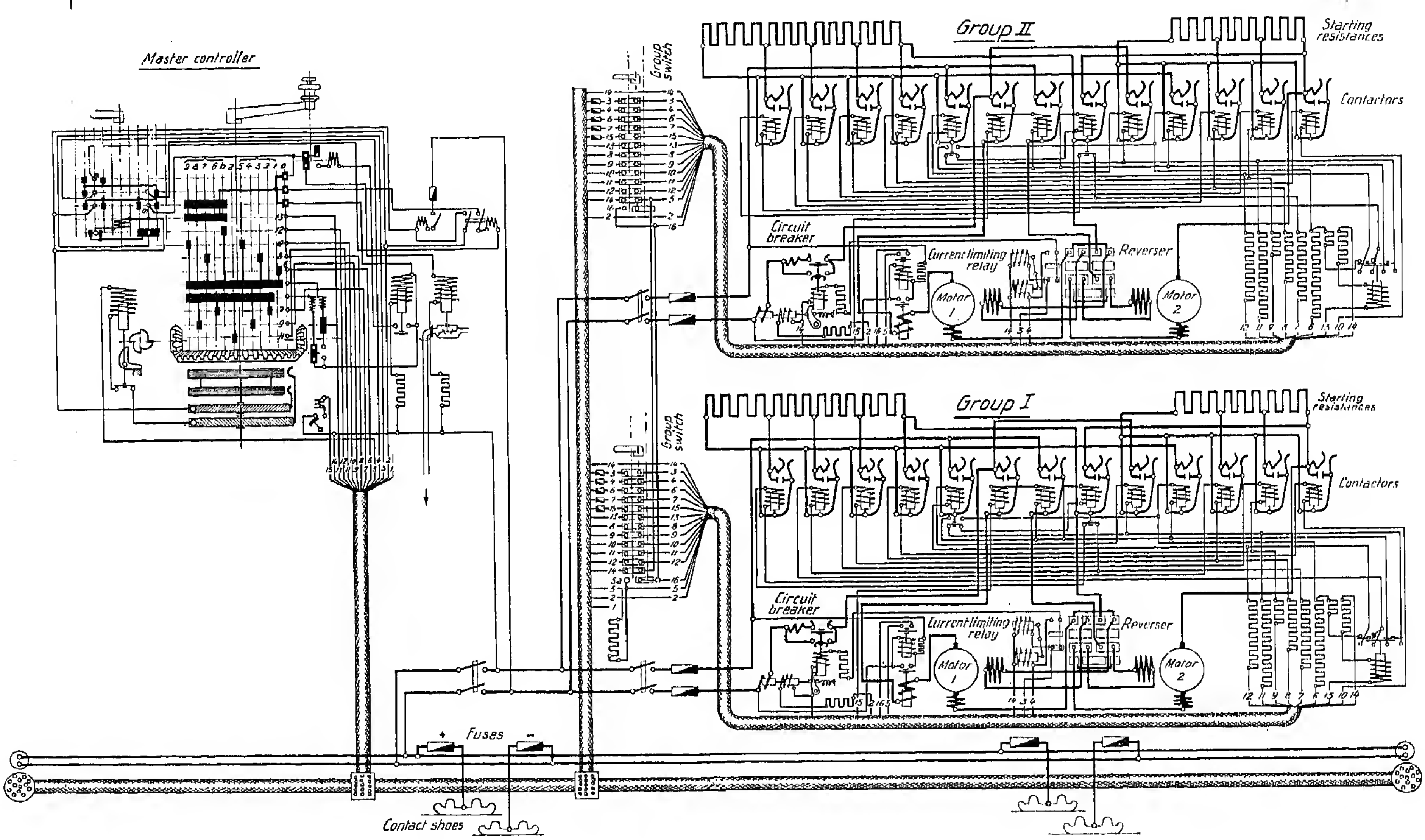


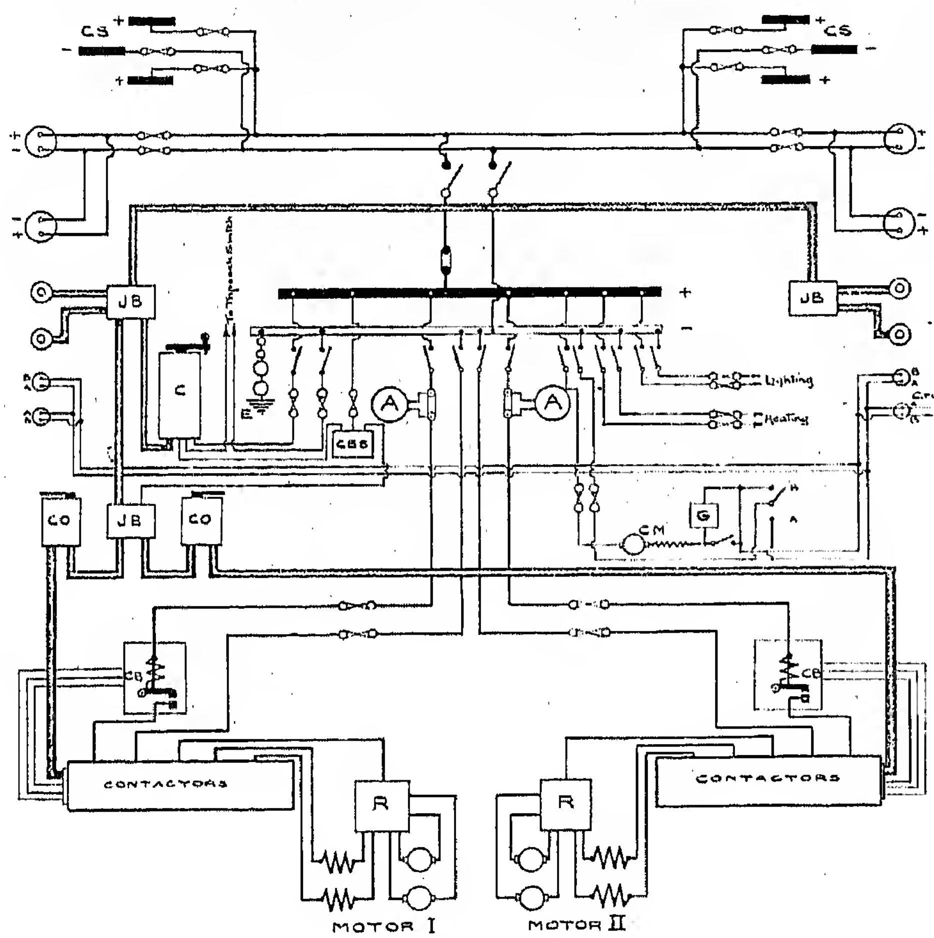
Fig. 13. Multiple Control for automatic and non-automatic operation. 15016

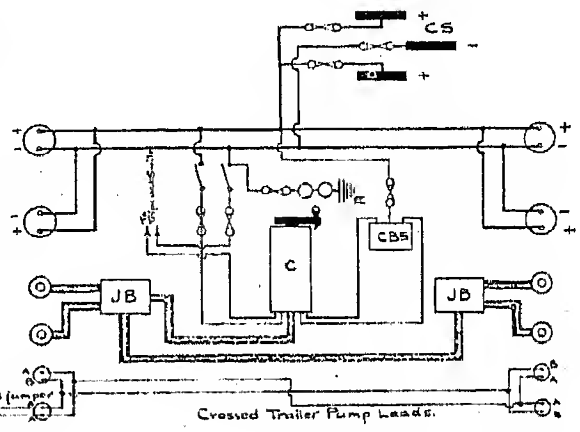
From the main switch the current is led to the two switches of the two groups of equipments. The control leads of the 2 groups pass through a multiple group switch; with this arrangement any control circuit can be cut off at will.

The motors have, as already stated, an hourly rating of 250 B. H. P. measured at the wheel rim. All motors were tested on the test bed of the Oerlikon Company either

by the L. & N. W. Rly Co's representative or by an expert nominated by them; the following trials were carried out:

1. Measurement of temperature rise during and after one hour's run.
2. Overspeed test at motor speed corresponding to train speed of 56 m. p. h.
3. Checking of the characteristics by running the machine in both directions.
4. Insulation tests with 2,000 volts A. C., hot.
5. General insulation tests.





17053

Fig. 14.
Simplified diagram of connections.

CS = Contact Shoes
JB = Junction Boxes
C = Master Controller
CBS = Master Switch for Circuit Breaker
CB = Circuit Breaker
R = Reverser
A = Ammeters
CM = Compressor Motors
CO = Group Switch
G = Compressor governor

Motors picked out at random were subjected to efficiency trials, and to a load test with 140 B. H. P. and 400 volts.

The motors are totally enclosed and self-ventilated by means of fan bolted to commutator end-plate. The cooling air for motors may be taken by means of flexible pipe connection from a duct communicating with exterior at a point of underframe where the air is comparatively pure and free from track or brake dust. At present, however, the intake openings are blanked off as the motors are so amply dimensioned that they do not exceed the guaranteed temperature rise in service. The motors are supported on one side by bear-

ings on driving axles; on the other side the motors are fitted with noses held between compressed rubber blocks attached to the transom. The gearing has a ratio of 1 to 3.3. Both gear wheel and pinion are made of tempered tool steel; the gear wheel is in one piece and pressed on to the axle. The gearing is running very quietly and giving entire satisfaction.

The motors when developing 250 B. H. P. — their one hour rating — and with a supply pressure of 575 Volts, have a speed of 620 r. p. m., and an efficiency of 87%, including losses in gearing. The maximum speed is 1400 r. p. m. A special feature of the motors is the yoke carrying the brush holders, which is of cast steel; mica insulation is used throughout. The armature of motors is bar-wound and the conductors are

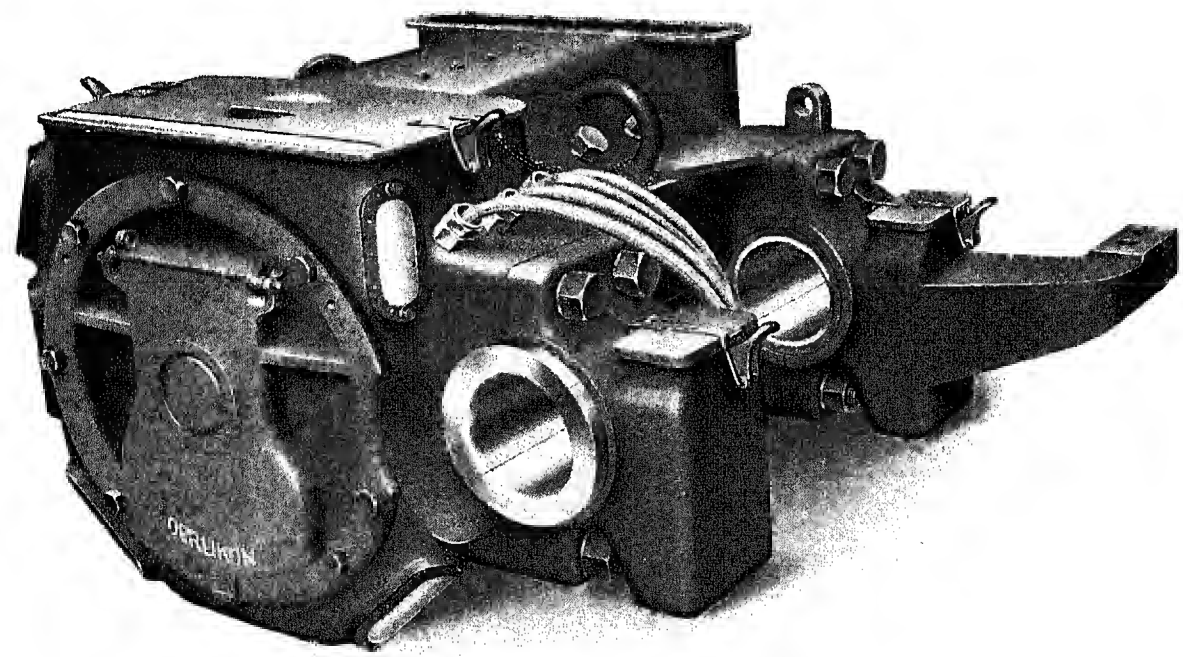


Fig. 15. Traction Motor. 12721

mica insulated, in the slots. The field and auxiliary pole coils are built up of copper strip. Perfect commutation is obtained with these machines. It may be of interest to mention here that a motor of this type wound for a pressure of 2400 volts, has given, on test, 250 B. H. P. on one hour service and developed continuously 150 B. H P.; this machine has also dealt with the overloads stipulated without flashing over or sparking.

The following are a few particulars regarding the motors for the L. & N. W. Rly equipments:

Diameter of armature	18.9" (480 mm)
Width of core	12.6" (320 mm)
Number of slots	53
Number of commutator segments	159

Diameter of commutator	16.9" (430 mm)
Number of brush holders	2
Number of brushes per holder	4
Weight without gearing	6600 lbs (3000 kilos)

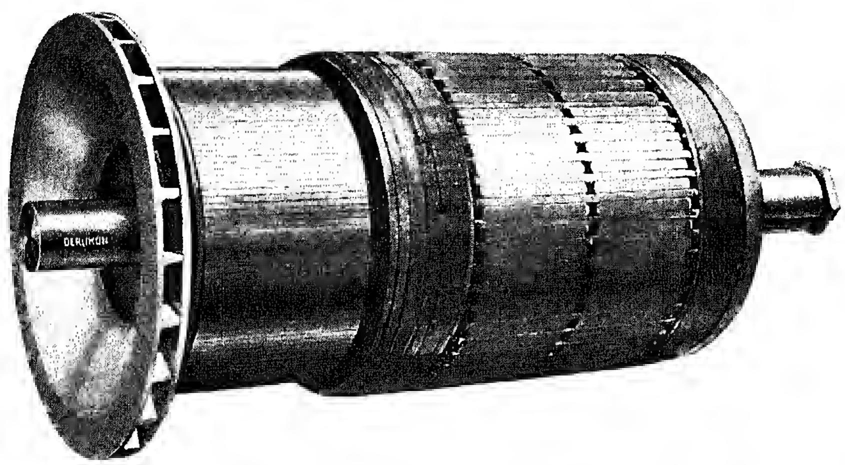
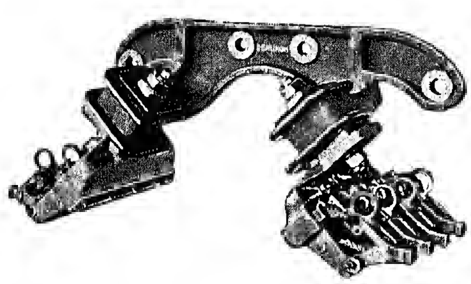
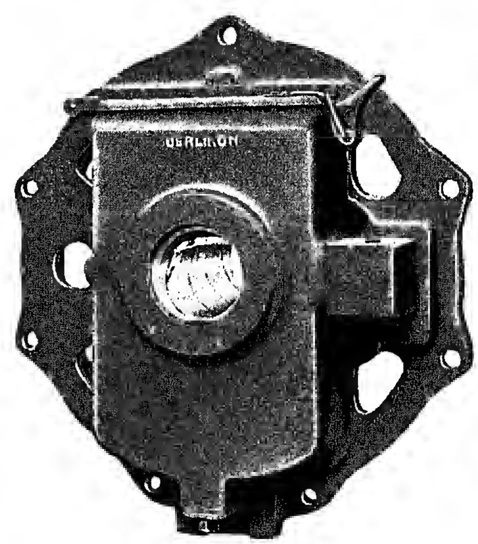


Fig. 16. Armature with Fan. 12748





12757 Fig. 17. Brush holders with End Bearing Shield. 12753

For starting up and regulation, 13 contactors are provided for each two motor group; these contactors are fitted with main and arcing contacts with magnetic blow-outs. They are electro-magnetically operated, very simple in design and very strong in construction; the wear of these contactors has proved to be very small. Built for 400 amps. at 360 to 630 volts, they are capable of breaking double their normal current without difficulty.

The circuit breakers have a double break and are provided with magnetic blow-out; they are operated electro-magnetically and are fitted with adjustable overload releases. Two main fuses are provided in addition to the circuit breakers for protecting

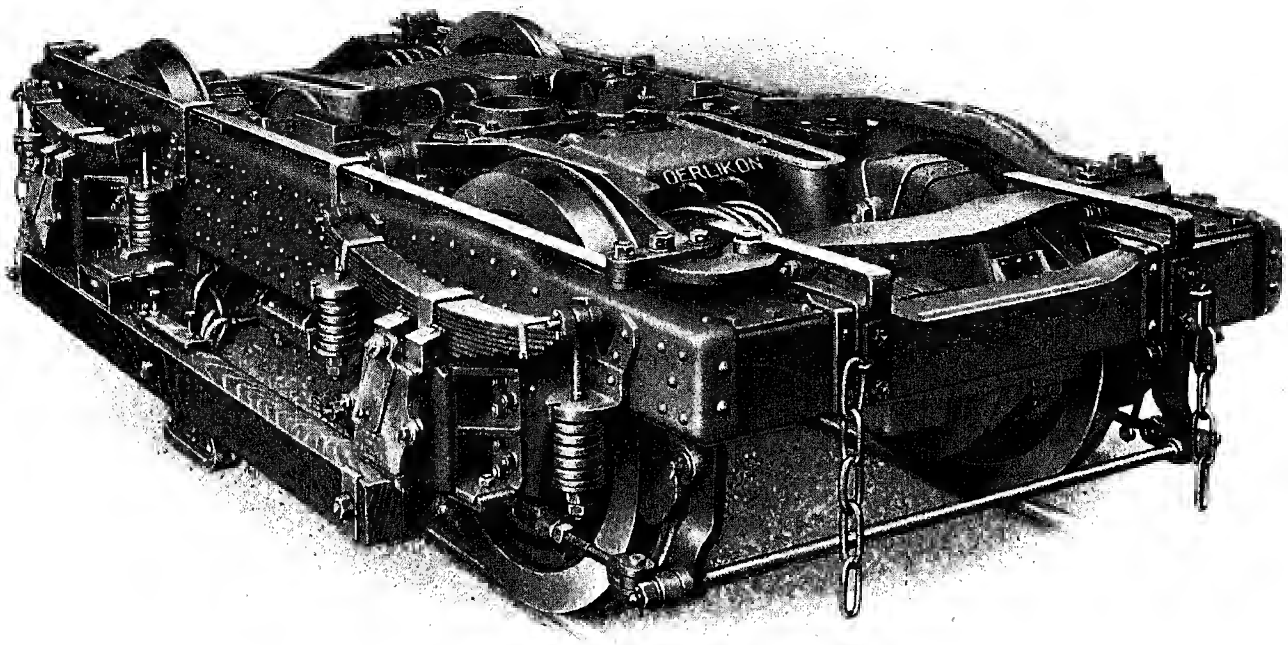
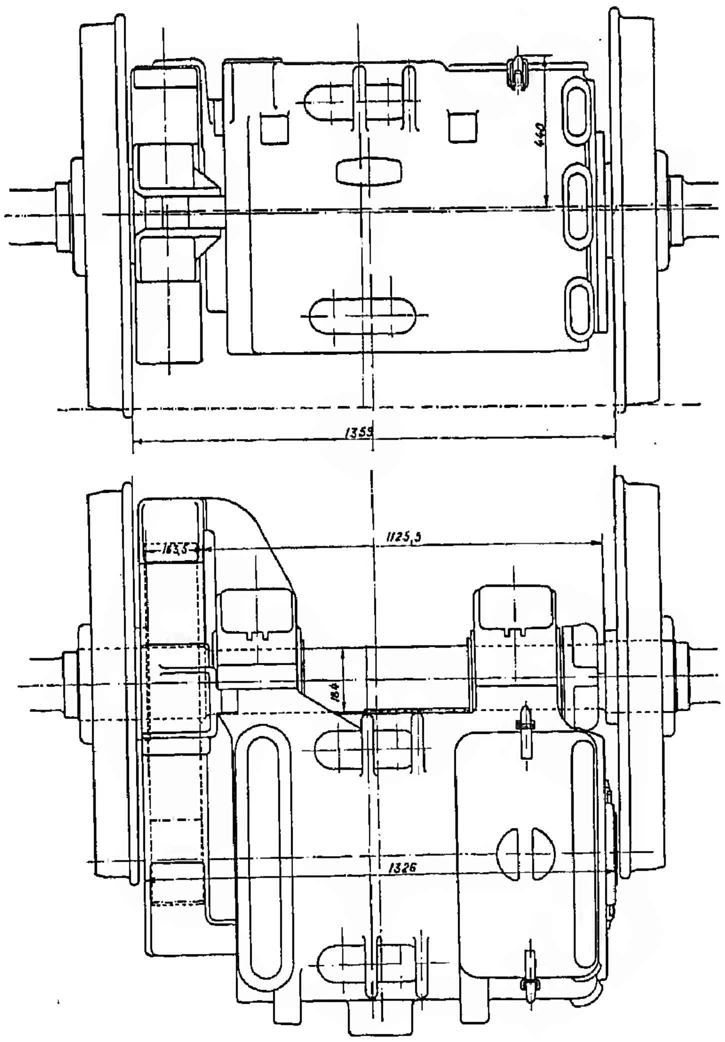
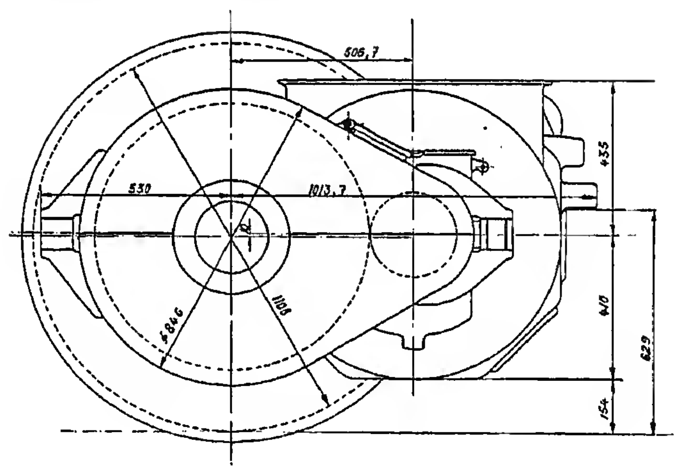


Fig. 18. Bogie of Motor Coach with Motors in position. 13500





14281

Fig. 19. Outline drawing of Motor, with gearing.

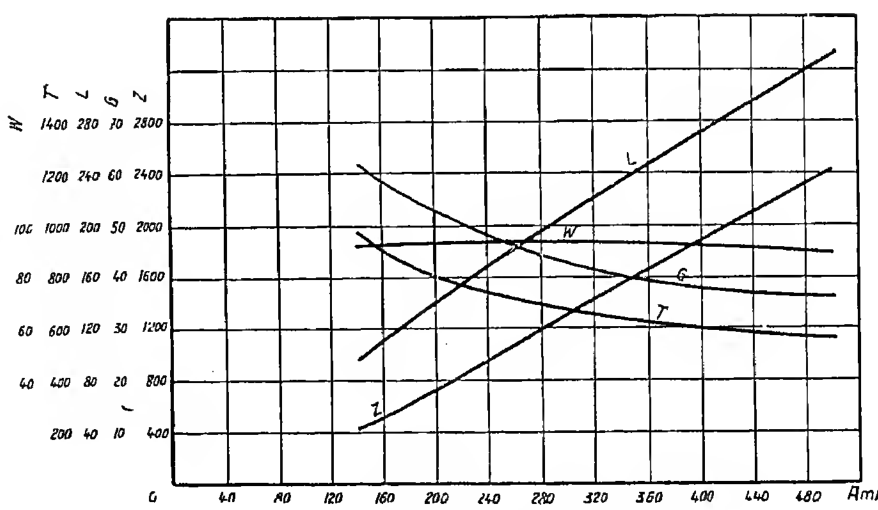


Fig. 20. Characteristics of Motor. 14279

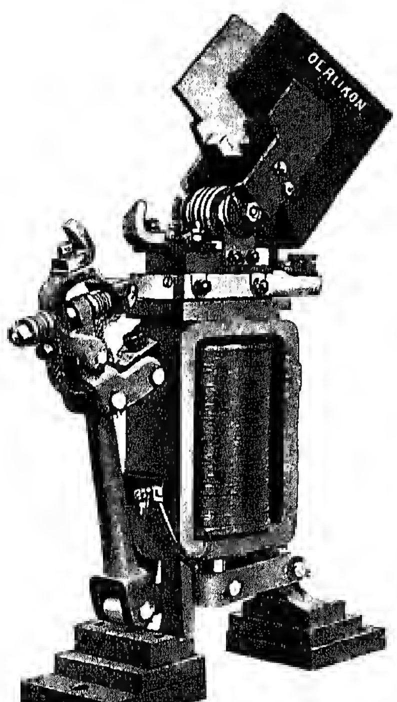
Tractive effort and output are measured at wheel rim.

W = Efficiency %
G = Speed km. p. h.
L = Output H. P.
Z = Tractive Effort kg
T = Rev. p. m.

the motors, each motor group having one circuit breaker and two fuses. If necessary, the circuit breakers can also be operated by hand.

Each of the two groups is provided with an electrically operated reverser; the latter is interlocked with circuit breaker in such a way that the breaker of any group can only be closed when the corresponding reverser is in the position indicated by reversing key on the master controller. The starting resistances are built up of substantial cast iron elements of special design; they are carried by mica insulated steel bolts, fitted in iron frames.

The motor and contact shoe fuses consist of copper strips which can easily be replaced; they are held in suitable clamps mounted in oak fuse boxes, the latter being lined with fire proof material and iron bound in such a manner as to secure a proper blow-out effect.



13354 Fig. 21. Contactor, 400 amps., 630 Volts, with upturned arc chute.

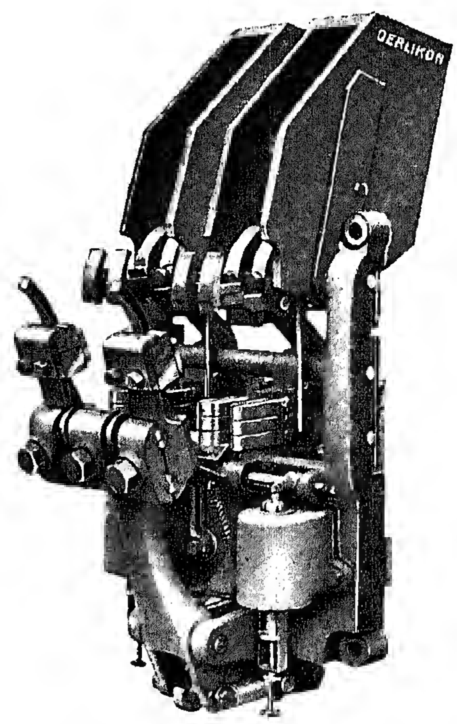


Fig. 22. Main Circuit Breaker, 800 amps., 630 Volts, with upturned arc chute. 12563

The controller is designed, as formerly stated, for automatic as well as non-automatic operation. It is provided with „Dead Man's" handle so arranged that, during operation, the driver has to depress by hand a push button fitted in the controller handle. As soon as the push button is released, the control circuit of the contactors is broken and the brake relay actuates the air brake. Nine starting steps are provided, five for series connections and four for parallel connections of motors, the 5th and 9th steps respectively being running positions.

The change-over from series to parallel connections of motors is effected, without break, by means of so-called bridging connections. During automatic operation, the controller spindle and drum move independently, the latter being actuated by a ratchet mag-

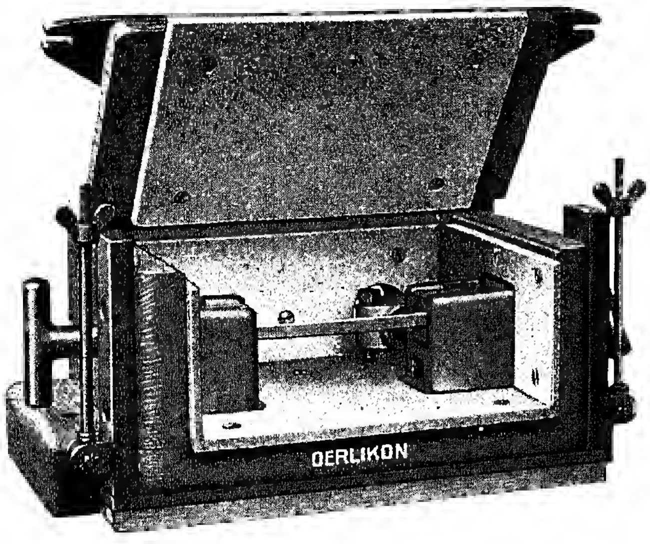


Fig. 23. Main Fuse, 2000 amps., 630 Volts. 16985

net; if the position of controller handle and drum coincide, the circuit of ratchet magnet is open; when, however, a relative angular displacement occurs, owing to the controller being moved to a given position, the circuit of ratched magnet is closed and the ratchet gear causes stepwise motion of drum until the latter reaches position corresponding to that of controller handle. The opening and closing of ratchet magnet circuit is effected by means of two contact fingers which are fitted to carrier at lower end of controller spindle and slide on contact segments mounted on drum; connection between contact fingers and ratchet gear is ensured by two contact rings carried by controller spindle and contacts on stationary portion of controller. When the motion of controller handle is reversed, the drum is carried back with it by means of an interlocking notch.

A current limiting relay is inserted in the circuit of the ratchet apparatus so that forward motion of the controller drum is only possible when the motor current does not exceed a certain value, previously fixed. The driver can, therefore, set his controller handle immediately in the desired running position; the ratchet apparatus will then cause the drum to revolve, the speed being regulated by the current limiting relay.

The controller drum is provided with the necessary contact segments for bringing into play the number of contactors corresponding to each speed step. When the controller is not required to operate automatically, the controller drum is coupled to the controller handle by means of a simple clutch actuated by a knob on the top plate of controller; the latter operates then as on ordinary controller; the automatic gear is, in this case cut out and does not interfere, in any way, with the non-automatic operation of controller. Interlocking control contacts are fitted on two contactors only, this having been found sufficient to satisfy conditions specified. This simple design of contactor gear has proved entirely successful, and has given the best result during the many years it has now been in service.

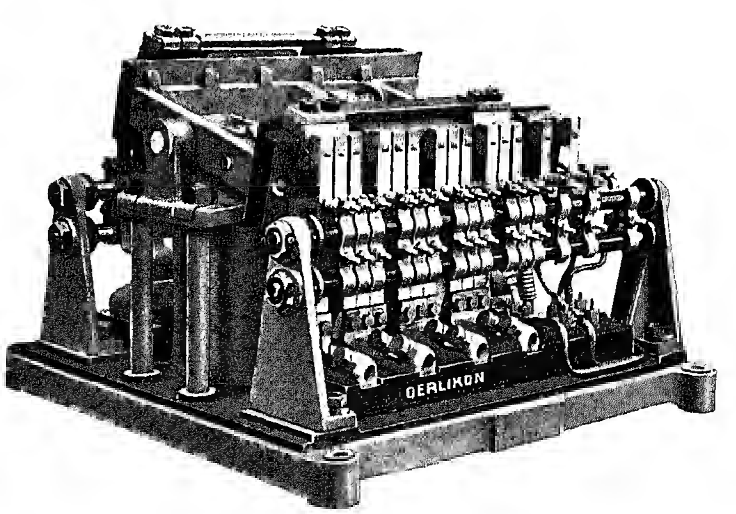


Fig. 24. Reverser. 13361

The operating coils of contactors are in series for any position of controller. In order to keep the value of resistance constant for every controller position, the operating coils cut out are replaced by resistances in series. The control circuit of the contactors is arranged so that no interruption of current takes place when passing from one position to the next; furthermore, the circuit of contact segments is broken in a central blow out operated by controller drum; in this way, all arcing between fingers and contact segments of controller drum is eliminated.

For changing over from series to parallel connection, a relay is provided which permits of the utilisation of the same control leads for both control positions; in this way four control wires can be dispensed with.

All cables are placed in seamless steel tubes, and joints are made in cast iron junction boxes, except in the case where the wires are connected to apparatus.

The weight of the electrical equipment which, as stated before, amounts to about 20 tons, is made up as follows:

		Lbs.	Kilos
4	Motors including gearing	28,600	13,000
26	Contactors	3,300	1,500
2	Circuit breakers	374	170
40	Couplers for busline, control leads, and for compressor, lighting and heating connections	1,100	500
6	Relays (2 series-parallel, 2 brake, 2 no-volt)	132	60
3	Switchboards	440	200
2	Reversers	550	250
9	Sets of contact shoe collecting gearing	1,320	600
2	Controllers	880	400
13	Main fuses	660	300
2	Group switches	88	40
2	Current limiting relays	44	20
2	Sets of starting and regulating resistances	1,980	900
2	Sets of control resistances	154	70
4	Control and heating switches	44	20
	Lighting and erection material	4,334	1,970
		44,000	20,000

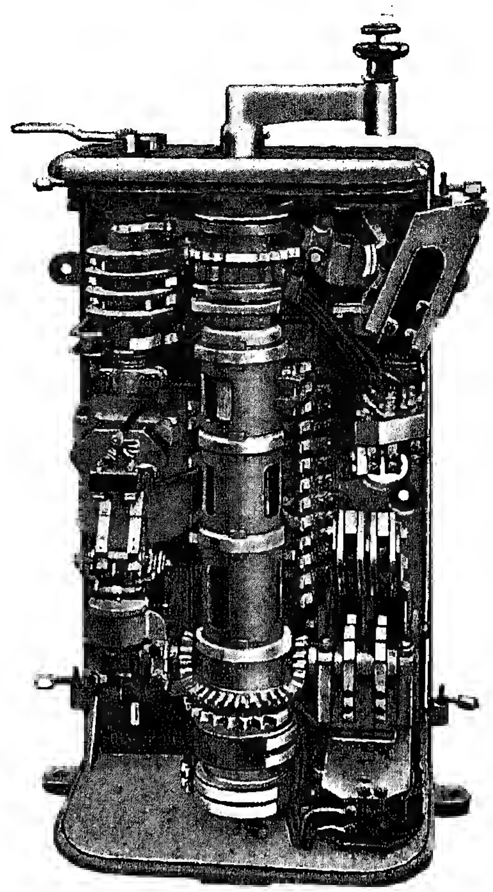


Fig. 25. Master Controller for automatic and non-automatic multiple control.

13349

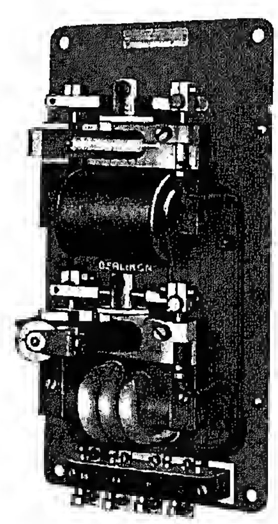


Fig. 27. Current Limiting Relay with cover removed.

14003

PERFORMANCE AT TESTS.

All train units have been tested on the Willesden—Watford Line, or on other sections of the system. Average figures, taken from the acceptance certificates of the train units 30 E to 47 E, for about 20 trial runs including starts, are given below; the length of run was 12.252 miles (19.7 Kilometres) with 11 stops of 20 seconds each. The average distance between stops was 1.114 miles (1.79 Kilometres).

Train No.	Train Composition	Starting Acceleration			Energy Consumption in Watt Hours	Maximum Current per Motor Amps.
		Miles per hour per second	Metres per sec²	Per ton mile	Per ton Kilometre	
30 E 33 E	6 Coach	1.44	0.63	66.8	42.3	400
31 E	3 "	1.45	0.65	75.2	47.5	410
32 E 34 E	6 "	1.54	0.68	70.4	43.7	420
35 E 36 E	6 "	1.31	0.59	68.5	42.5	400
37 E 38 E	6 "	1.38	0.62	64.0	39.8	420
39 E 40 E	6 "	1.40	0.63	64.1	39.8	420
41 E 42 E	6 "	1.39	0.62	57.0	35.5	420
43 E 44 E	6 "	1.46	0.65	61.7	38.4	440
45 E 46 E	6 "	1.36	0.61	48.9	31.0	420
47 E	3 "	1.40	0.63	68.1	42.5	420

Guaranteed figures, as well as average values based upon the figures in the above table, are given below in order to permit of comparison.

	Average values obtained at tests	Guarantee figures
Starting acceleration	1.4 m. p. h./sec 0.63 metres/sec²	1.2 m. p. h./sec 0.535 metres/sec²
Energy consumption	40.3 watt hours per ton kilometre 64.9 w/h per ton m.	41 watt hours per ton kilometre 66 w/h per ton m.
Maximum motor current when starting	417 amps.	500 amps.

Owing to the good acceleration obtained, the condition stipulating that a speed of 24 miles (38 Kilometres) per hour was to be reached, when starting, within 20 seconds, could be easily satisfied.

The temperature rise of the motors and starting resistances, in continuous service, proved also to be very low. After a 17 hours normal service on the Earls Court — Willesden Line, the following maximum temperatures were measured, with an atmospheric temperature of 24° C.: —

Commutator copper	70° C.
Armature core	75° C.
Starting Resistances	160° C. (Cast iron).

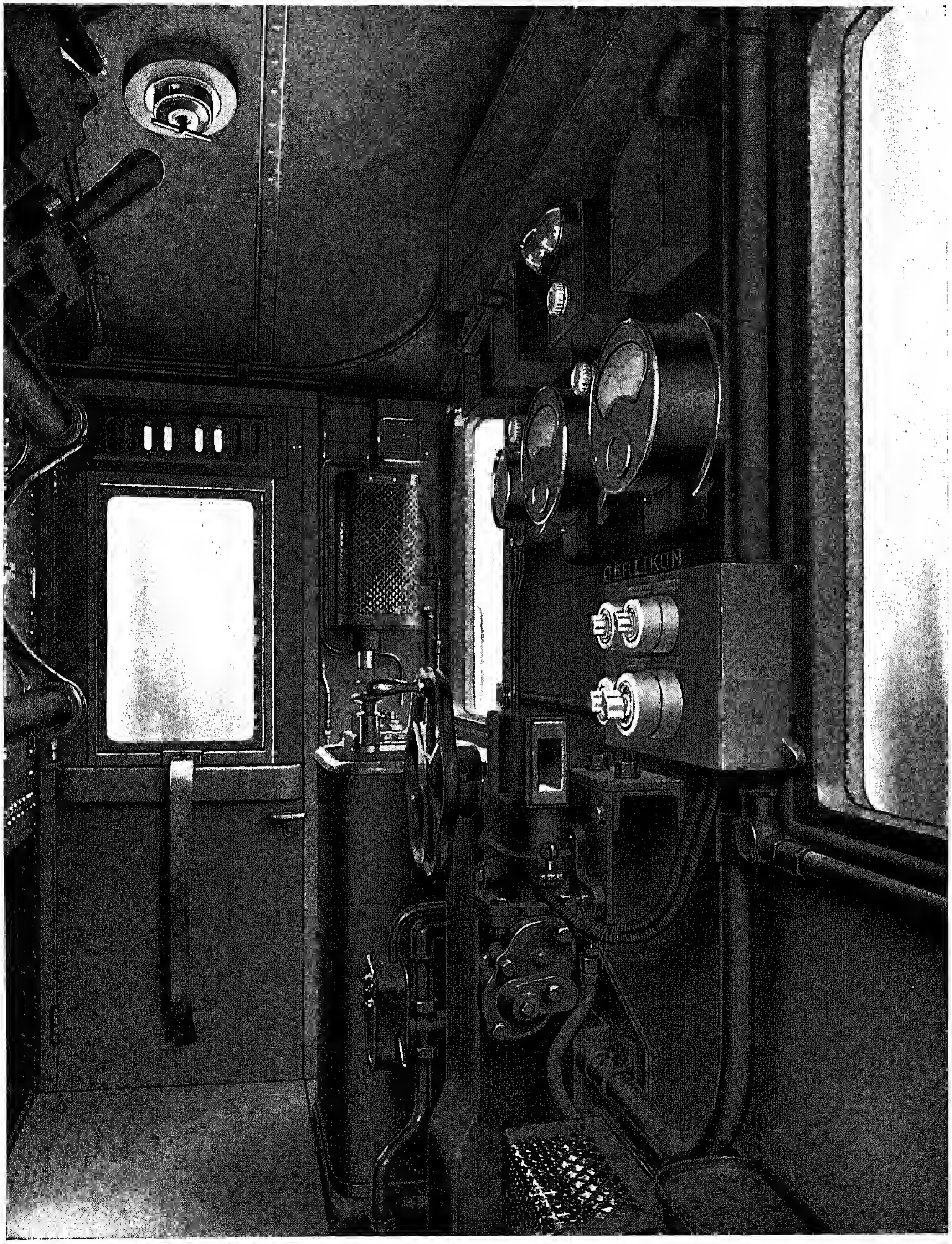


Fig. 27. Driver's Cab in Motor Coach. 13759

The electrical equipments have now been in service for nearly six years, and the soundness of their design and construction has now been fully demonstrated. There can also be no better proof of the satisfaction this material is giving, than the fact that a repeat order for 30 further Three-Coach Trains has been placed with the Oerlikon Company.

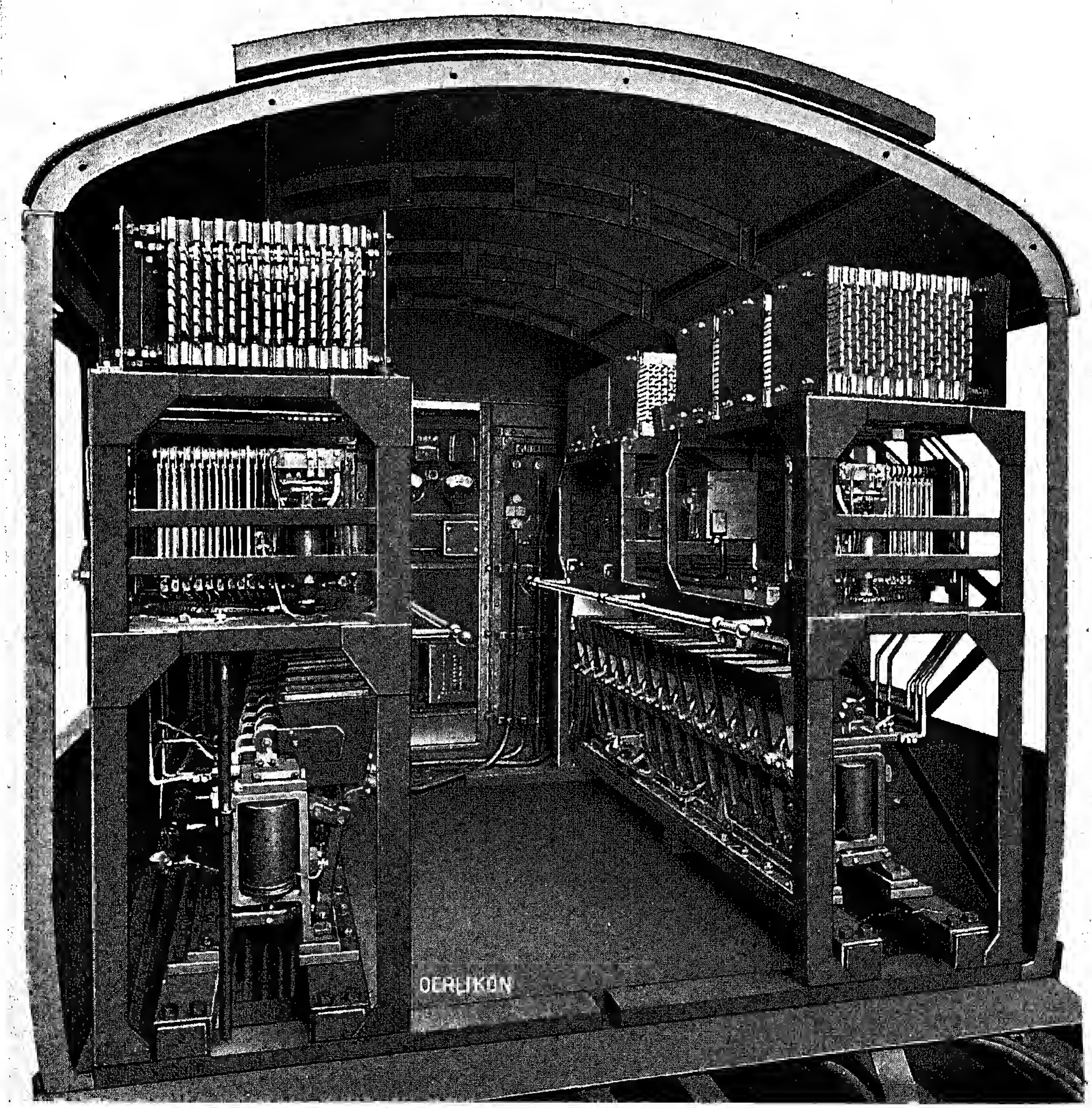


Fig. 28. View of Apparatus Cabin during erection. 13497

BULLETIN OERLIKON

No. 61/62 — July/August 1926

Contents:

D. C. Regenerative Braking as used on Express Locomotive No. 242 BE1 of the Paris, Lyons & Mediterranean Rly. (P. L. M.).

In Bulletin No. 21, we gave a few particulars regarding this locomotive as well as a description of its main features; we now propose to deal more in detail with the method adopted for regenerative braking during downgrade operation. The stipulations laid down in this respect in the specification for the locomotive show the great importance the P. L. M. Railway Co. attached to the full utilisation of all the advantages of electric traction. The clauses in question provided that the regenerative braking equipment was to be capable of limiting the train speed to 35 to 40 km. per hour (22 to 25 m.p.h.) on inclines of 1 in 33, with a trailing weight of 300 tons and a locomotive weight of 120 tons, i. e. with a total train load of 420 tons. When designing the locomotives, the Oerlikon Company was thus faced with the problem of devising a method of D. C. regenerative braking such as could be applied with every guarantee of safe operation, under the exacting conditions imposed by main line service.

The locomotive was subjected to regenerative braking tests in May 1925 on the gradients ranging up to 1 in 33 of the section Culoz-Modane of the P. L. M. Railway, where the line is in the course of electrification. Since then, there have also been further opportunities of testing the reliability of the method of regenerative braking in question. These various trials could be carried out without difficulty owing to the line being connected to the supply through rotary converters, and the results obtained have been entirely satisfactory. In the course of these tests, as much as 1500 KW. was generated by the locomotive and fed back into the three-phase system. It may be pointed out, in a general way, that regenerative braking is dependent upon the electrical conditions at overhead line, and is affected by all changes which take place there. Such variations have a much more unfavourable effect on the motors, when the latter are working as generators than when they are operating as motors. This is due to the fact that, while the motors are used for traction purposes, the armature and field of machine are in series (see Fig. 1) — an arrangement which ensures great stability as the ratio between armature and field ampere-turns remains constant and the motor is little affected by pressure fluctuations, such as are encountered in practice. When, however, the motors are utilised for generating purposes (see Fig. 2), only the armature and interpoles are actually in series between overhead line and earth, as the field winding has to be cut out of the armature circuit; consequently, the large amount of inductance this winding represents and the throttling effect it would have on the current are no longer of any use for stabilising purposes. At the same time, the ratio between armature and field ampere-turns is no more constant and, in certain cases, there is a possibility of excessive pressures between commutator segments, when the motor is working as a generator. We encounter here the same difficulties as arise occasionally in the case of motors running at a high speed with greatly reduced field. It is a well-known fact that D. C. series motors cannot be used in the same way as shunt wound motors for feeding back into the system, without alteration of their fundamental mode of connection, as self-excitation renders series generators quite unsuited for regenerative braking; consequently, provision has to be made for separate excitation and, under such conditions, the pressure fluctuations at overhead line would have to be compensated by the impedance of the armature connected between line and earth, and by the resulting current fluctuations. As the impedance of armature is small, the variations in current required for the compensation of a rise or drop in pressure in the armature, with constant excitation or E. M. F., would be great. If the motor is, for instance, working with the field reduced to the critical point, before the current rush, these unfavourable conditions will be further accentuated when the current rush actually takes place. Such pressure fluctuations will thus result in flash-overs on the commutator, specially at high speeds, and in a very variable braking effect. In the case of shunt wound motors, which are excited directly from the system, the pressure variations of supply act simultaneously on the armature and field, so that a damping effect takes place and no special difficulties are encountered in this direction. In order to reproduce these characteristics of the ordinary shunt wound motor, with regard to stability, in the case of a separately excited series motor, the arrangement for regenerative braking must be such that the pressure fluctuations act not only upon the armature but also, at the same time, upon the field. The first idea which presents itself is to feed the field of exciter from the supply; this is, however, not identical with the pure shunt arrangement, with regard to magnetic inertia of system. Some of the best known methods resorted to, in this connection, reside in the use of an exciter with counter-current winding (counter-compound) carrying the braking current, or of an ohmic damping resistance through which the current of the armature and field of motor flow in the same direction, during regenerative brak-

ing. A sudden alteration in the current generated gives rise, in both cases, to a change in field in the opposite direction, and thus prevents current rushes in their inception. It can be said that, with regard to rapid and effective action, the latter arrangement is preferable, as the magnetic inertia of exciter does not come into question then. The adoption of either of these methods has, however, an unfavourable effect on the braking curves, and this constitutes a very undesirable feature of the arrangement. These curves which show the relation between braking force and speed no longer embody the favourable shunt characteristics (i. e. practically unaltered speed with varying braking effect) of the plain shunt wound motor, or of the separately excited series motor without damping device. These curves, after starting from a lower value, tend rather to become tangential to a vertical line, corresponding to the regulating position at the time, once the armature current has reached a sufficiently high value, and, after this, bend backwards. The shape of these curves is nearly exactly the reverse of that of the corresponding curves of the series motor, which tend asymptotically towards the axis of ordinates, but for small values of armature current.

In practice, this means that, on each braking notch within a certain range of braking, great variations of speed take place for small changes of braking forces, and that, in the dangerous range of braking, the motor is liable to race, in view of the decreasing braking torque, in the same way as a series motor relieved of its load. This lack of stability of speed during braking, which is, it is true, damped to a certain extent owing to the inertia of train is dangerous and not permissible for braking under service conditions. The range of braking must at least be limited, but this does not necessarily conduce to safety in operation, as the limits set down may, for some reason or other, be passed involuntarily. In this respect, the pure shunt characteristics are preferable to all others, as they do not permit of considerable changes in speed with varying braking force. The solution of the problem must thus be found in a compromise between shunt characteristics and sufficient stability of current.

The method described hereafter marks a considerable step in this direction, the braking curves obtained being much more favourable and the mode of operation far more satisfactory than in the case of the two above mentioned methods, where a counter-compound winding or a damping resistance is resorted to. The arrangement in question, which was used on the P. L. M. locomotive, is represented diagrammatically in Fig. 3. Two resistances r_1 and r_2 having a fixed relative value*) are provided in the armature circuit, the one connected direct between earth und armature being preferably an inductive resistance. These two resistances are linked up, on the earth or armature side, to the counter-current winding of the exciter, which is also designed accordingly. The field winding of the motor working as generator is fed by the exciter through these two resistances in parallel. The exciter is direct coupled to an electric motor, with as constant a speed as possible. With this arrangement, the counter-current winding of exciter weakens the field of exciter and motor very energetically, when the current in armature, or braking current, has a low value; consequently, the braking curves are given an upward bend, but, at the same time as the armature current increases, this action gradually disappears, that is to say, the upward displacement of curve is prevented. As a result, the braking curves which would otherwise bend upwards very sharply, in the case of heavy currents, are flattened out into a line which is nearly, if not perfectly, straight, at least over the range where braking is permissible from the point of view of commutation, heating and maximum speed, that is to say,

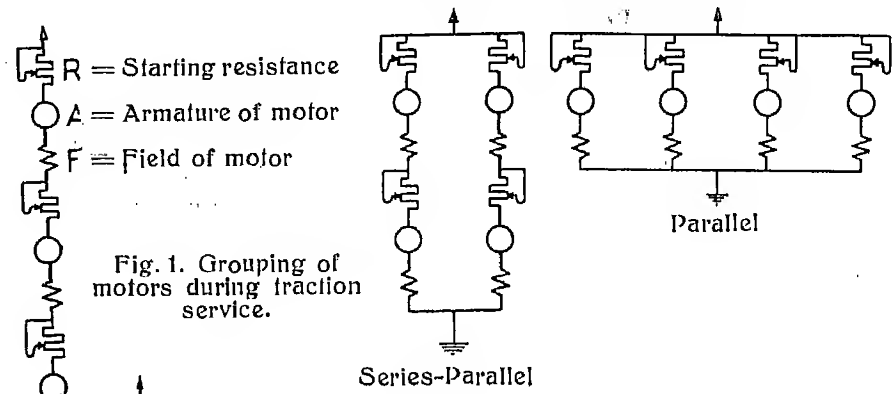


Fig. 1. Grouping of motors during traction service.

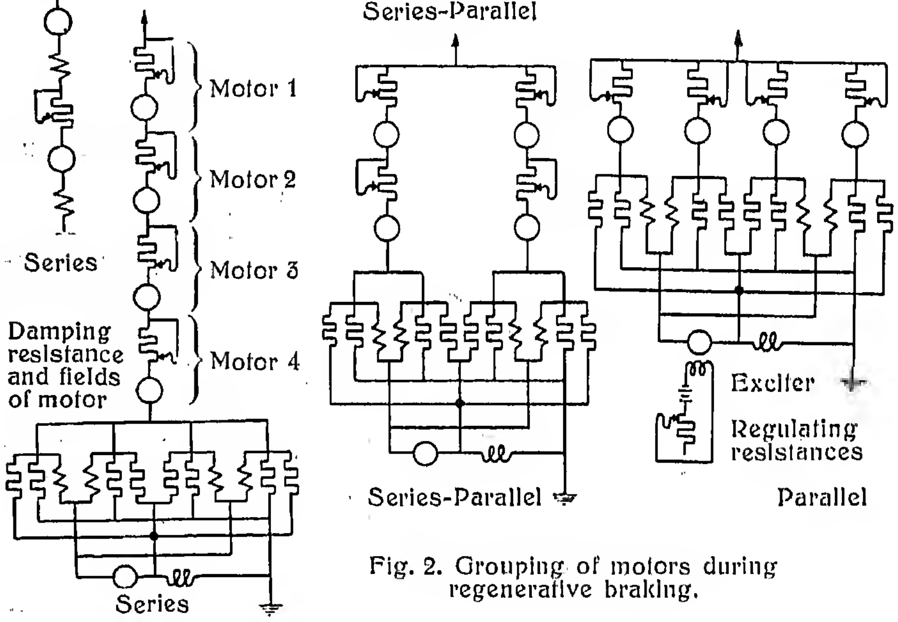


Fig. 2. Grouping of motors during regenerative braking.

over a large range. The shape of the braking curves is merely dependent upon the value of damping resistances and design of counter-current winding. For the purpose of illustration, we are giving, in Fig. 4, braking curves such as would be obtained with one or the other first mentioned methods, in the case of the P. L. M. locomotive, when the motors are working in parallel, for instance.

As can be seen, the speed and current curves bend upwards tangentially to the corresponding braking force line, a feature which is, it is true, favourable with regard to current rushes, when passing from one braking notch to the other, but highly undesirable from a working point of view. Fig. 5, on the other hand, represents braking curves for

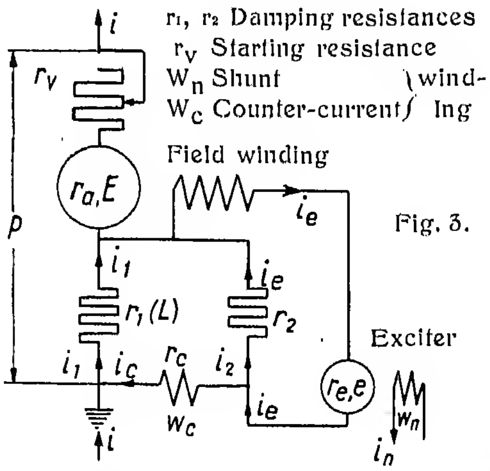


Fig. 3.

*) We shall refer again to the starting resistance connected in the armature circuit, as shown in Fig. 1, and used as series resistance.

the arrangement according to Fig. 3, but where no series resistances are provided, and shows clearly the flattening out effect of this mode of connection on the curves. Let us compare, for instance, curve 9 in Fig. 4 with curve 8 in Fig. 5. Both curves start from 68 to 69 km. per hour (42 to 43 m. p. h.). In the case of the first curve, the maximum braking effect is reached for a value of braking force as low as about 7000 kgs., while, with the second curve, the highest braking effect is far from being attained when the braking force has a value of 9000 kgs. Fig. 6 gives the braking curves for the three possible modes of grouping of motors, namely; series, series-parallel and parallel, when the starting resistances of motor are also used as series resistances for the regulation of braking. From a working point of view, the use of these resistances presents great advantages with regard to stability and safety in operation. The favourable effect of these resistances is specially marked at low speeds, under which conditions the braking curves become steeper, to a permissible extent, but still remain approximately straight; consequently, the changes in current and braking force, when passing from one notch to the following, are damped. These curves are specially interesting and show how the braking process can be controlled in a very reliable way over a large range. With the new arrangement we have described, the damping resistance can be left unaltered for all modes of grouping of motors, and at all speeds, this being also a notable advantage. Figs. 1 and 2 give the simplified diagrams of connections of motors on the P. L. M. locomotive, for running and braking. The arrangement adopted where the starting resistances are distributed between the motors during running and specially during braking prevents, in the case of series and series-parallel operation, a too great rise of the pressure to earth of the motors nearest the overhead line, even if the total pressure of motors should rise during service to twice normal pressure. While, on the one hand, the individual armatures of motors produce a rise in potential, the resistances, on the other hand, cause a corresponding drop in potential. The potential of the armature nearest the system is not greater than the pressure drop of the corresponding resistance; the potentials of the motors, when connected in series as shown in Fig. 2, are represented in Fig. 7. It is, to a great extent, owing to this distribution of starting resistances that regenerative braking can be brought into operation so surely. If all the resistances were connected in front of the motors, the potential to earth of the foremost motor would reach a considerable value, exceeding permissible limits, and it would be necessary, before being able to connect the motors to the system, to ensure equality of pressure by regulation.

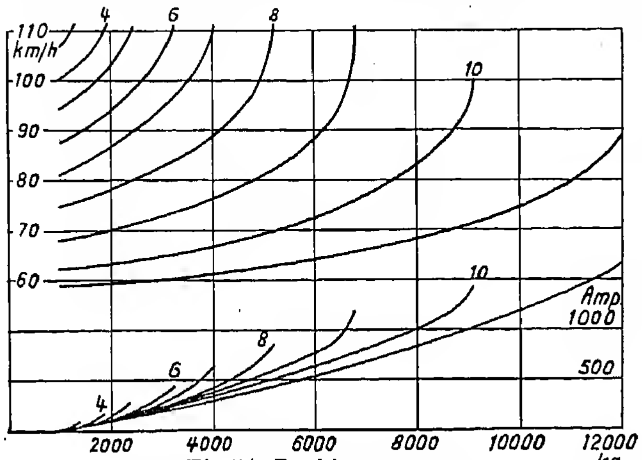


Fig. 4. Braking curves.

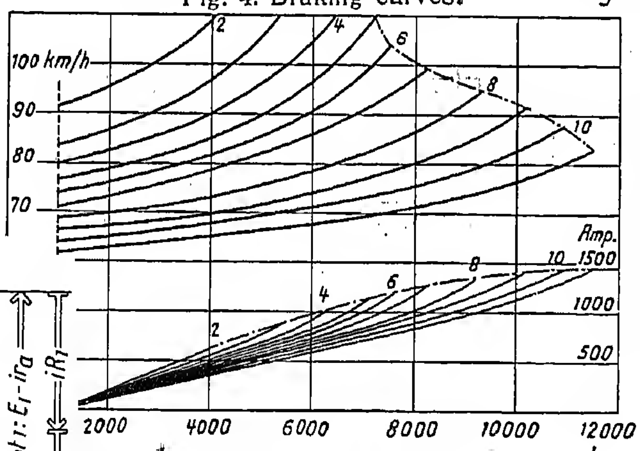


Fig. 5. Braking curves.

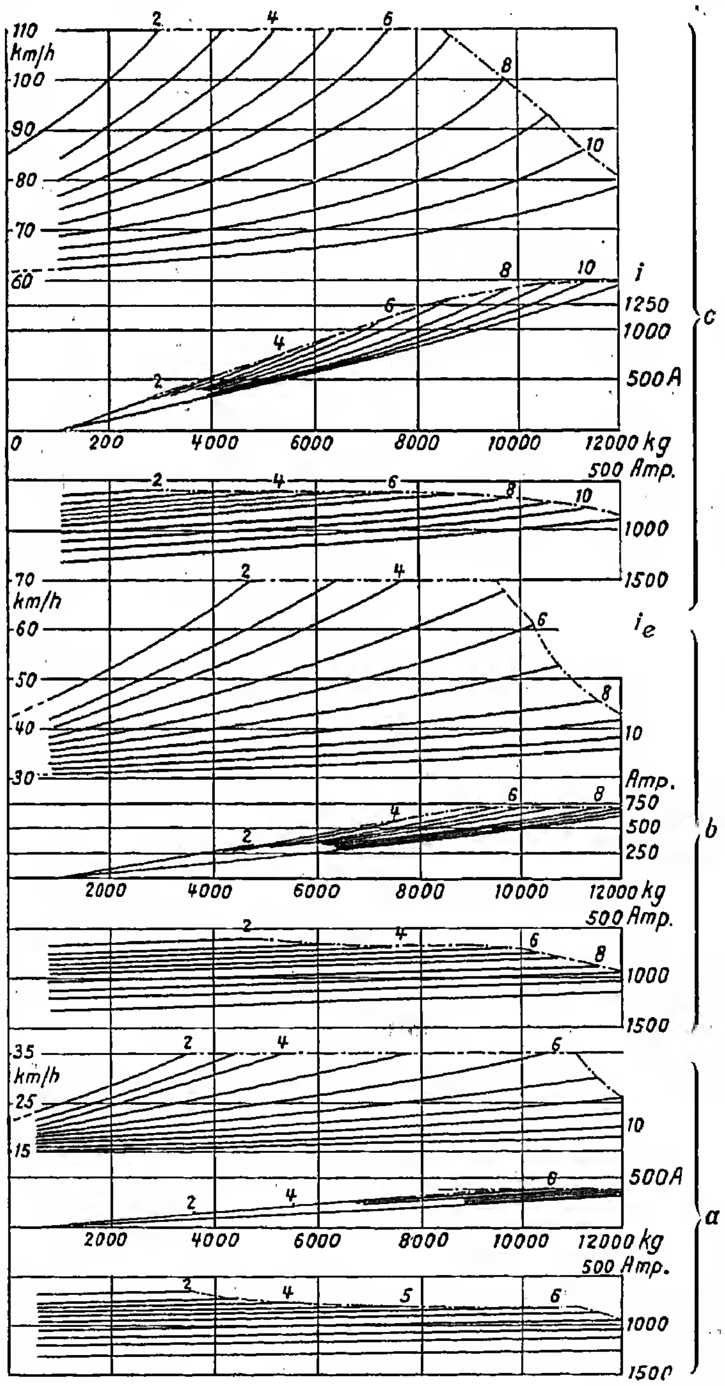


Fig. 6. Braking curves for a) series, b) series-parallel and c) parallel operation, according to Fig. 3.

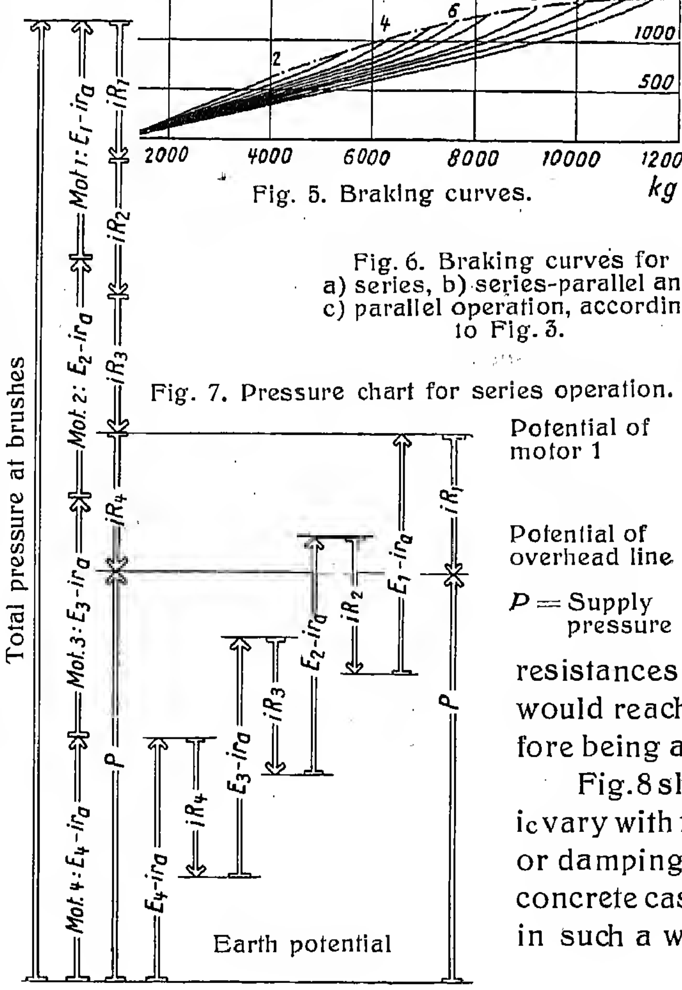


Fig. 7. Pressure chart for series operation.

Fig. 8 shows how the field current i_e, the braking torque m, the speed n and the counter-current i_c vary with the braking current i, when using the arrangements with counter-current winding alone or damping resistance alone, and with the new mode of connection, the curves being based on a concrete case. The fundamental excitation and the design of counter-current winding were chosen in such a way as to obtain for, $i = 0$, the same value of i_e, in the case of the three arrange-

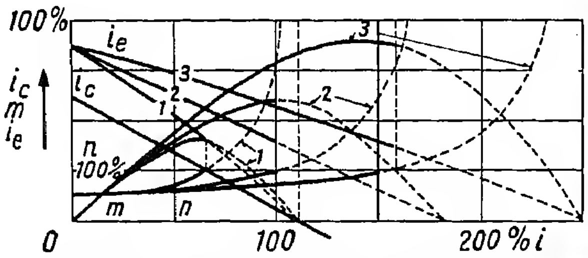


Fig. 8. 1) Braking arrangement with counter-current winding alone. 2) Ditto with damping resistance alone. 3) Ditto with resistance and counter-current winding.

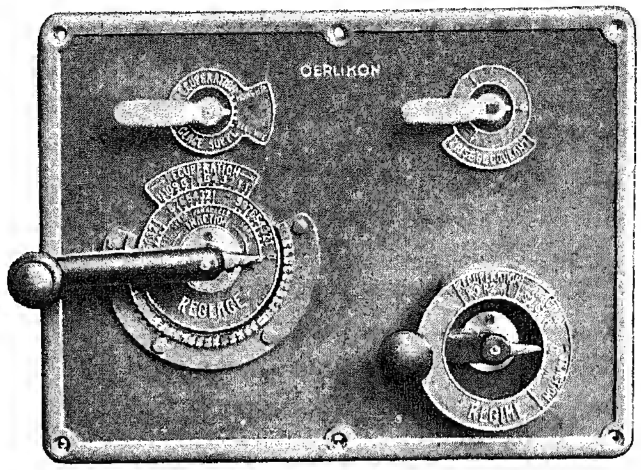


Fig. 9. Controller plate.

ments. The quantities r and w_c have been given the same value for the respective curves. The dotted extensions of the individual curves are only of theoretical interest, as they correspond to speeds which exceed the permissible 100 %. For commutation reasons, there is a further limitation in that i = approx. $2 i_e$. This means that the braking limits for the three arrangements are given by $i = 70\,\%$, $i = 90\,\%$ and $i = 110\,\%$ respectively. The range of braking is thus limited in the case of the two first arrangements by the maximum permissible speed and the current ratio assumed; with the new mode of connection, however, this is no longer the case and considerations as regards commutation are foremost. On the other hand, danger of racing is not as great as with the other methods. In view of this, the motor is, whenever possible, operated with a larger current ratio i/i_e, with $i/i_e = 2.5$ to 3 for instance. The limit value of i is then 125 % or 135 %. It will be seen from the above that, with the new arrangement, the stabilising effect of the damping winding is not eliminated by the counter-current winding, even when the current in this winding changes direction and strengthens the field; the latter conditions are encountered when the armature current exceeds a given value, that is to say, in the present case, when the current ratio is above $i/i_e = 2$.

On the other hand, the mode of variation of the braking torque, as shown by the curves, is of special interest; as can be seen, the braking torque increases to a maximum value, and then drops again to zero, which value corresponds to a speed infinity. In the neighbourhood of the maximum value of braking torque, the latter is no longer well defined, as two speeds correspond to a given braking torque; in practice, however, this range is not utilisable. In this respect, the three arrangements only differ in that the maximum torque is reached for a smaller or larger value of armature current; furthermore, with the new mode of connection, larger braking torques can be obtained, with the same adjustment of field current, for an armature current = 0. Fig. 8 shows also how the curves corresponding to the new arrangement are flattened out and what a large range of braking is obtained.

The above remarks regarding the character of the curves apply, more especially in the case of the new arrangement, to stable conditions, when there are neither variations in pressure nor switching operations. In the case of variations in pressure and switching operations, we have changes in current which are not affected in the same way by the reactance L and the resistance r_2 shown in Fig. 3. If there is such a reactance L, it will throttle the current inductively and divert it to the resistance r_2. The diverted current has then to overcome the full resistance r_2 which, in the present case, is three times greater than the permanent resistance $r = \frac{r_1\, r_2}{r_1 + r_2}$. The damping effect is thus correspondingly greater.

The additional equipment provided on the P. L. M. locomotive for regenerative braking includes the following:—

1 exciter set with compound wound motor and shunt wound generator.
2 additional drums on the main controllers for the regulation of traction motors.
1 set of stabilising resistances per motor.
2 reversers with running and braking positions.
1 maximum pressure relay.
4 emergency and two isolating electrically-operated valves for use in conjunction with the compressed air brake.

The weight of the additional equipment is about 2.7 tons, that is to say, it represents 6 % of the total weight of the electrical equipment, which amounts to about 45 tons.

The only additional handle required for the controller equipments in question, as compared with equipments for traction service alone, is the small handle for additional regulation. The "réglage" handle which is used for cutting out the starting resistances during running and for altering the grouping of driving motors is also utilised during regenerative braking, but only for varying the resistances in the main circuit and in the field circuit of exciter. The "régime" handle, which is used during running for changing the direction and for weakening the field of driving motors, is utilised during regenerative braking for altering the grouping of driving motors.

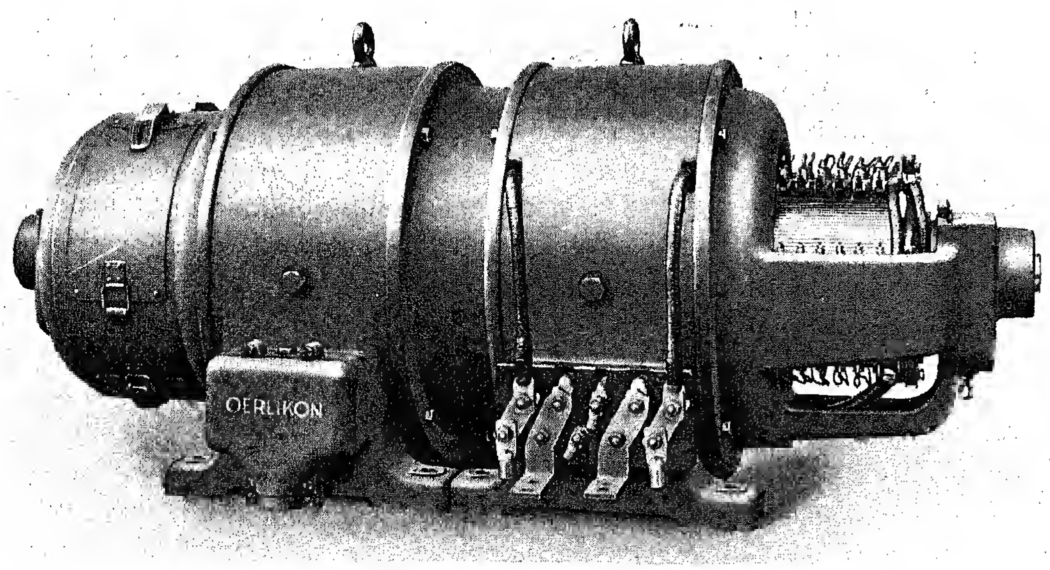


Fig. 10. Exciter set.

The passage from traction to regenerative braking takes place as follows:— The "réglage" handle is brought back from the running position to zero, the "régime" handle is set for the grouping of motors corresponding to the speed at the time. The motors are then switched on, without waiting until the supply pressure and the pressure of motors are equal, and the "réglage" handle is operated again; in this way, the series resistances are cut out step by step and the field of driving motors strengthened by increasing the excitation of exciter. When the last notch, i. e. the eleventh notch of each grouping of motor is reached, there are no series resistances left in the braking circuit, and the exciter and driving motors are fully excited.

When switching on with the regulating handle, there is a current rush, in one direction or the other, according to whether the action of the motor is that of a motor or of a generator, this depending upon the value of speed. If supply pressure and E. M. F. of motors happen to be identical when switching on, no current flows when the handle is on notch 1.

If the grouping of motors has to be altered during regenerative braking, in order to reduce or increase the braking speed, the "réglage" handle must be brought back to the position 0 and the "régime" handle reset. The motor current must, therefore, be entirely interrupted, which is not the case for traction service. Once the "régime" handle has been brought to the desired position, the "réglage" handle can be operated again. The reverser disconnects the field windings of motors from the armatures, in the braking position, with a view to separate excitation, and the brake switch connects them to the exciter; the latter, which has a continuous rating of 38 KW at 38 volts, then ensures the excitation of motors. During braking, the current for the control and lighting circuits is supplied by a battery of accumulators with a capacity of 132 amp-hours. When, however, the motors are on traction, the necessary current is derived from the exciter dynamo, which is used in conjunction with a regulator and connected across the battery. Special electrically-operated valves prevent braking by compressed air during regenerative braking, while, on the other hand, they ensure that the compressed air brake comes into play automatically in the case of failure of regenerative braking.

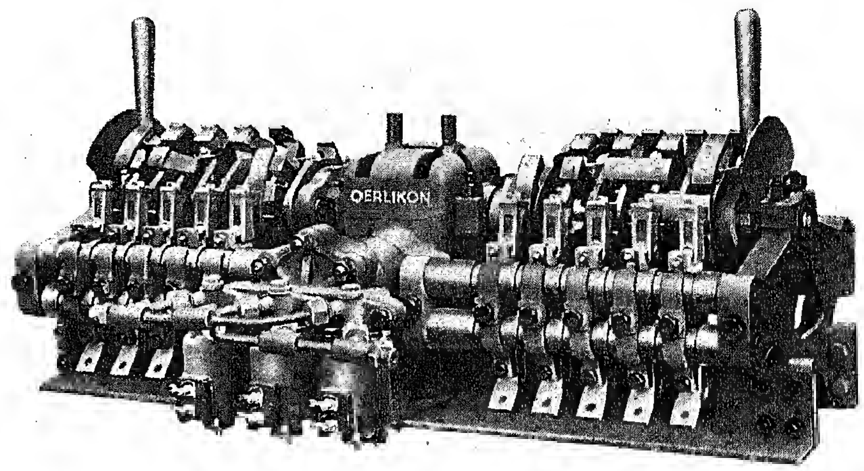


Fig. 11. Reverser.

Tests for the Determining of the Heat Radiation of a Cooler for Transformer Oil.

The tests we propose to describe were carried out on a cooler of the type used for cooling equipments of oil immersed transformers (see Fig. 1a). The following are a few particulars regarding the design of cooler and the arrangement adopted:-The cooler consists of a stack of 68 vertical iron tubes, circular in section, with an external diameter of 30 mm and an internal diameter of 27 mm. The tubes are welded at either extremity to an end-plate, and a sheet iron cover is fitted over the latter so as to form a small chamber, branches being provided for the inlet and outlet of oil. The complete cooling equipment comprises 40 such coolers connected through a common pipe to the transformer. The 40 coolers are disposed in parallel, so that the oil can circulate through the system, as a result of the natural upward tendency of the warm oil in the transformer. The equipment is further arranged in such a way as to permit of the insertion of a circulating pump in the system, when it is desired to work with forced oil circulation.

The oil is admitted at the top of cooler and escapes at the bottom. The air in the neighbourhood of the tubes rises, as a result of the natural upward tendency of warm air and, in the process, carries away the heat from the tubes.

As the 40 coolers are arranged close together, the air cannot circulate freely. In view of this, a wooden screen was provided round the cooler during the tests, as shown in Fig. 1b, in order to limit the access of air and thus reproduce more exactly the actual working conditions.

Fig. 1a shows the cooler and testing equipment with screen removed. The cooler, 1, is connected to a length of pipe, 2, containing electric heating coils arranged along half its length. Forced oil circulation is ensured by means of a Sulzer pump, 3, direct coupled to an electric motor, 4. The oil measuring equipment consists of a Schmid integrating meter, 7, in the pressure pipe, with a flow indicator, 6, inserted after it. A sluice valve, 7, is provided at the bottom of the pipe, 2; this valve is closed when working with the circulating pump, and open for natural oil circulation. In the case of the latter mode of operation, the two valves, 8 and 9, in the suction and pressure pipe respectively, have to be closed.

The whole system is filled with thin transformer oil. A length of pipe, 10, is provided at the top of the pipe, 2, in order to permit of the expansion of oil, due to heating.

When working with the circulating pump, the oil leaving the cooler through the lower branch flows through the suction pipe, 11, into the pump, 3, then through the meter, 5, and the indicator, 6, into the heating pipe, 2, and from there returns to the cooler through the upper branch.

The temperature of oil was measured at the points t_1, t_2 and t_3 by means of thermometers calibrated to $^1/_{10}{}^0$ C. On the other hand, in order to be able to determine accurately the heat radiation of the heating pipe, 2, itself, readings were taken of the external metal temperature at the points t_4, t_5 and t_6. Furthermore, the temperature of air was measured at a

distance of about 500 mm from the heating pipe, at the points t_7, t_8 and t_9. The temperature readings on the cooler itself were taken with the thermometers arranged as shown in Fig. 6, on the side of Table III. The temperature of the air rising from the cooler was measured at different points by means of the same thermometer as for the readings at t_7, t_8 and t_9.

The room temperature was ascertained at a distance of about 5 metres from the testing installation.

The heating coils were made up of three star-connected units fed direct from the system. Readings were taken of the supply pressure and current in one phase.

Preliminary tests. The object of these tests was to determine the heat radiation of the various parts of system, the radiation being considered under the following heads:—

1. L_k = Heat radiation of the cooler itself.
2. L_h = Heat radiation of the heating pipe.
3. L_p = Heat radiation of the pump set, including meter and pipe connections.

L_h and L_p could also have been taken together, but the present tests have shown that it was preferable to consider them separately. Though L_h and L_p were only determined at the time of the main tests, we are, however, including them here.

a) Heat radiation of heating pipe. After dismantling the cooler, the two branches were sealed by means of a plate and the valves, 8 and 9, hermetically closed. The system was then filled again with oil, after which the heating coils were switched on and permanent temperature conditions awaited.

As, in this case, the oil was not circulating, the only temperatures to be considered when determining the heat radiation were the metal temperatures t_4, t_5 and t_6 and the room temperature t_{room}; consequently, the results obtained were independent of the state of oil inside the heating pipe. The figures arrived at (see Table I, tests 1 to 3) can thus be applied without modification to the main tests, when the state of oil inside the heating pipe was different.

The heat radiation tests in question were carried out with the heating coils arranged in the lower part of pipe. The average temperature t_m was determined graphically from

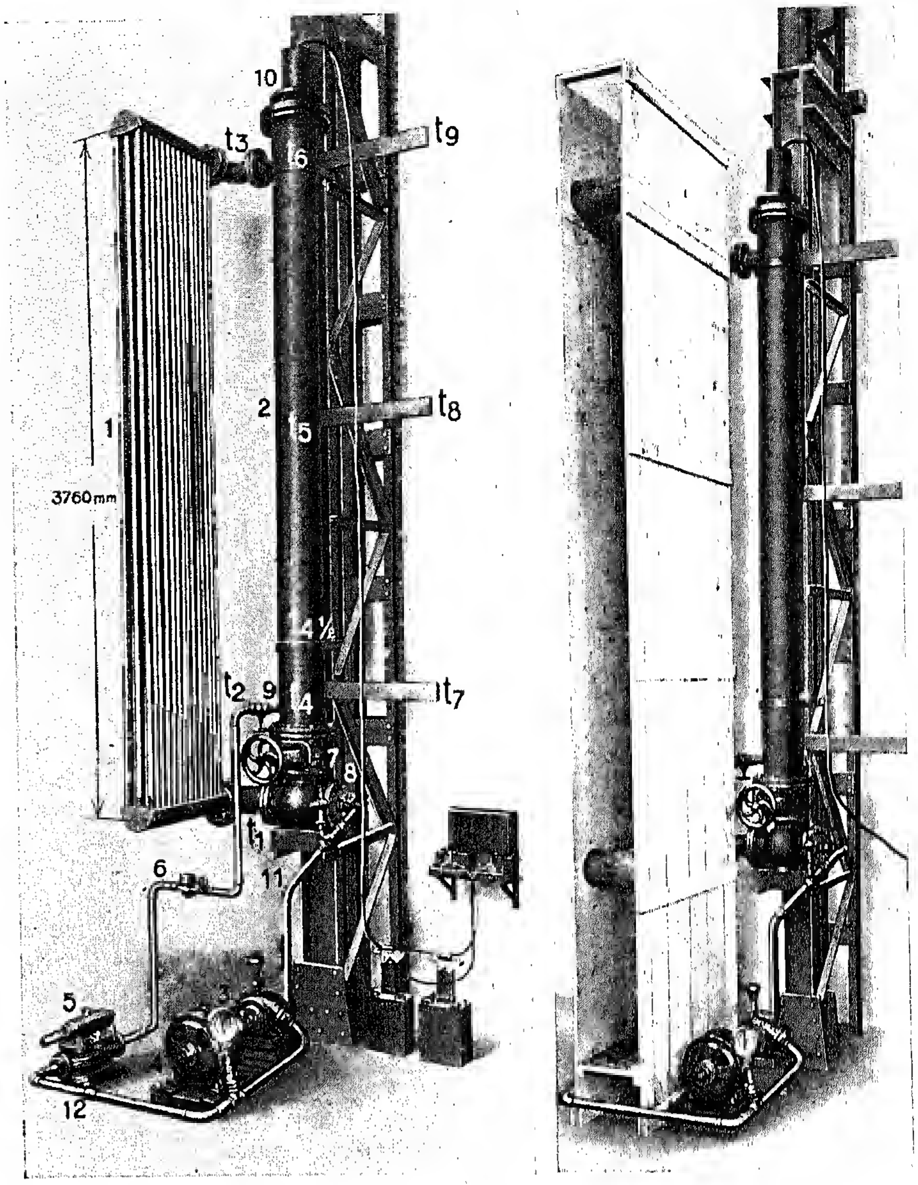


Fig. 1a—1b. Testing installation. Cooler with and without screen.

the temperatures t_4, $t_{4^1/_2}$, t_5 and t_6. In Fig. 2, we have plotted a curve with the values obtained for $t_m - t_{room} = \Delta t_h$ as ordinates and the quantities of radiated heat L_h, in KW, as abscissae. This curve which shows the relation between Δt_h and L_h can be represented by the following equation:—

1) $$L_h = 0.0345\,(\Delta t_h) + 0.000204\,(\Delta t_h)^2 \text{ kW.}$$

Table I		Test No.	1	2	3	4	5	6	7	8	9
Oil temp. at heating pipe, below		t_1	—	—	—	34.8	62.1	79.4	32.8	54.1	74.6
" " after the pump		t_2	—	—	—	35.5	61.55	77.6	38.7	54.4	69.5
" " at heating pipe, above		t_3	—	—	—	34.7	62.9	80.1	33.6	57.5	80.1
Quantity of circul. oil, in litr. per min.		V	—	—	—	25.45	26.3	26.7	3.84	3.65	4.00
Oil pressure after the pump, kg/cm²		P	—	—	—	1.90	1.87	1.87	1.90	1.89	1.86
Power consumed by motor		kW	—	—	—	1.700	1.420	1.350	1.520	1.360	1.260
" " by heating		kW	0.807	1.760	2.720	0	2.460	4.340	0	1.730	3.750
" " in all		kW	0.807	1.760	2.720	1.700	3.880	5.690	1.520	3.090	5.010
Barometric press., in mm Mercury		B				719	720	720	727		
Room temperature, in °C		t_{room}	15.0	13.3	13.0	11.8	14.3	12.4	13.1	12.5	12.5
Temperature at outer surface of heating tube	below	t_4	16.0	22.5	26.3	28.3	48.3	60.8	21.5	31.0	36.5
	450 mm above t_4	$t_{4^1/_2}$	29.0	48.3	64.2				26.0		
	in the middle	t_5	38.5	58.2	76.8	27.0	50.0	64.0	27.7	46.4	66.0
	above	t_6	39.1	56.0	71.7	27.3	50.0	61.6	27.2	46.8	63.8
Temperature of air at a distance of 0.5 metres	below	t_7				11.8	14.6	13.2		12.6	13.0
	in the middle	t_8	16.0	15.0	15.7	12.4	15.8	14.1	14.6	13.8	14.5
	above	t_9	16.4	15.5	16.0	12.9	16.3	14.8	14.9	14.1	14.8
Metal temperature of the 2″ gas pipe	below	t_{32}	—	—	—	27.4		69.0	24.9	45.4	66.8
	above	t_{33}	—	—	—	31.0		72.3	28.3	48.5	67.6
Average value $(t_{32}+t_{33}):2$		t_m'	—	—	—	29.2		70.65	26.6	46.95	67.2
Do. for heating pipe (determ. graph.)		t_m	36.0	54.3	71.5	27.5	49.4	62.1	26.7	42.6	58.2
$t_m - t_{room}$		Δt_h	21.0	41.0	58.5	15.7	35.1	49.7	13.6	30.1	45.7
$t_m' - t_{room}$		$\Delta t_k'$	—	—	—	17.4		58.25	13.5	34.45	54.7
$t_2 - t_{room}$		Δt_p	—	—	—	23.7	47.25	65.2	25.6	41.9	57.0
KW radiated by	heating pipe	L_h	0.807	1.760	2.720	0.591	1.462	2.221	0.506	1.223	2.005
	2″ gas pipe	L_k'	—	—	—	0.131	0.342	0.520	0.101	0.280	0.482
	motor, pump, meter, pipe connections	L_p	—	—	—	0.970	2.076	2.949	0.913	1.587	2.550

b) Heat radiation of pump, motor, meter and pipe connections. In order to determine the value of L_p, a small 2″ gas pipe was fitted in place of the cooler. After filling again the system with oil, the pump was put into operation, the sluice valve, 7, being closed.

The 2″ gas pipe radiates also a certain amount of heat. In fact, it was found by taking readings with thermometers, that the metal temperature of this pipe was a good deal higher than that of the heating pipe. This can be easily explained if it is borne in mind that the velocity of oil in the 2″ gas pipe is much greater than in the heating tube, which has an internal diameter of 250 mm, so that the transfer of heat from the oil to the metallic wall of the pipe takes place under much more favourable conditions in the case of the gas pipe; in other words, the temperature drop between oil and metal is smaller. The heat radiated by the 2″ gas

pipe must, therefore, also be taken into account; it can be calculated approximately by applying the following formula:—

2) $$L_k = L_h \times \frac{O_{k'}}{O_h} \times \frac{\Delta t_{k'}}{\Delta t_k}\ \mathrm{KW}.$$

L_h is the heat radiated by the heating pipe in the case of a temperature drop Δt_h; it is determined by means of the equation 1).
$O_{k'}$ = surface of the 2″ gas pipe = 0.7 m².
O_h = surface of the heating pipe = about 3.5 m².
$\Delta t_{k'}$ = average drop in temperature between the metallic wall of the 2″ gas pipe and the air of the room.

The radiated heat L_p is obtained from the equation 3).

3) $L_p = L - L_h - L_{k'}$ KW. L represents the total electrical energy supplied (motor + heating).

The values obtained are indicated in Table I, tests 4 to 9.

Let us now represent L_p as a function of $t_2 - t_{room} = \Delta t_p$. There would also be a temperature drop $t_1 - t_{room}$ to consider, in the case of the suction pipe, 11, but as this pipe is very short, it can be left out of account without appreciable error; on the other hand, the effect of this error is itself compensated as a result of the somewhat higher temperature in the pump. The curve showing the relation between L_p and $t_2 - t_{room} = \Delta t_p$ is plotted in Fig. 3. The point $t_2 - t_{room} = 0$ corresponds to light load operation of motor, 4, alone. For the purpose of determining this value, the motor was uncoupled, and the losses measured. The value obtained was 0.300 KW. The curve in Fig. 3 can also be represented by the following equation:—

4) $L_p = 0.300 + 0.0195\,(\Delta t_p) + 0.000307\,(\Delta t_p)^2$ KW.

We then obtain, for the cooler itself, the equation 5).

5) $L_k = L - L_h - L_p$ KW. L is the total electrical energy supplied (motor + heating).

L_h is the heat radiated by the heating pipe, in KW; it can be obtained from the equation 1). L_p is the heat radiated by the pump set, meter and pipe connections, in KW; it is derived from the equation 4).

Main Tests. It is now easy to arrive at the final results. For this purpose, tests were carried out with the cooler operating under the following conditions and subjected to a natural flow of air:

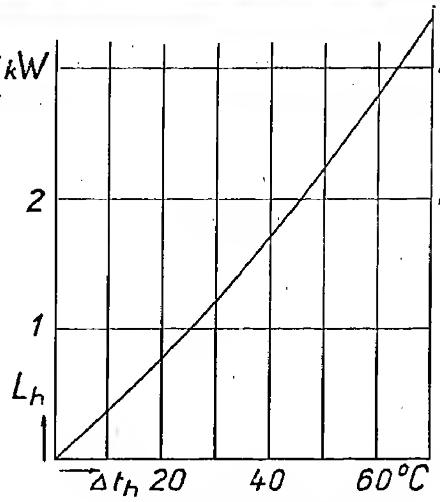


Fig. 2. Heat radiation of heating pipe.

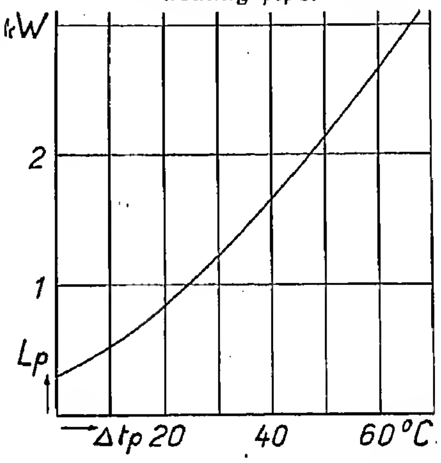


Fig. 3. Heat radiation of pump set, including meter and pipe connections.

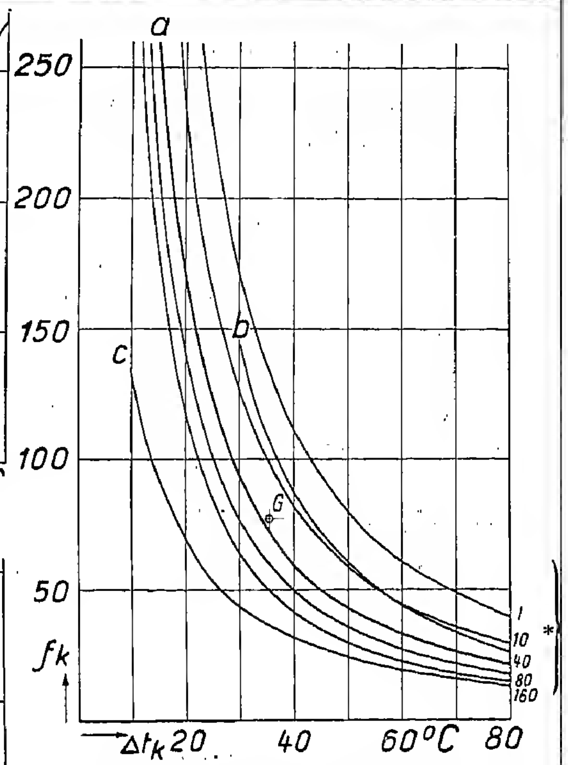


Fig. 4. Surface required for dissipating 1 watt.
a) with forced oil circulation, 40 l (normal)
b) with natural oil circulation, heating coils in the lower part of heating pipe
c) for heating pipe G = guarantee value
*) Quantity of circulating oil, in l/min.

1) with screen fitted and with natural oil circulation, at different oil temperatures and with different quantities of oil.
2) with the left side of screen removed.
3) without the screen.

The values arrived at are indicated in Table II. The quantity f_k = a cm²/watt represents the number of cm² of surface required to dissipate 1 watt, and gives an indication as to the efficiency of cooler; the external radiating surface of cooling tube is O = 232000 cm².

6) Hence $$f_k = \frac{232000}{(L_k)_{KW} \times 1000}\ \mathrm{cm^2/watt}.$$

Table II

		with screen																		without the left side		without screen	
	Test No.	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Oil temp. at heating pipe, below	t_1	44.1	28.4	35.6	45.1	46.2	47.8	50.3	43.3	40.1	32.0	18.3	21.2	48.4	66.2	32.3	26.0	29.0	33.8	50.7	43.8	29.6	42.8	29.6
„ „ after the pump	t_2	44.3	29.3	36.2	45.4	46.6	48.1	50.5	43.8	42.5	37.9	—	—	48.4	65.6	38.6	—	—	—	—	44.1	—	43.0	—
„ „ at heating pipe, above	t_3	44.5	29.0	36.9	47.4	48.6	50.8	52.8	46.8	53.4	55.5	46.0	80.7	51.7	72.4	61.0	46.8	54.6	63.5	84.5	47.0	53.4	45.9	52.2
Quantity of circul. oil, in litr. per min.	V	154	35.3	32.2	36.6	36.4	33.3	37.3	22	7.6	4 00	—	—	30.7	32.0	3.93	—	—	—	—	30.6	—	31.15	—
Oil pressure after the pump, kg/cm²	P	1.70	1.92	1.90	1.90	1.92	1.89	1.90	1.90	1.90	1.91	—	—	1.87	1.86	1.90	—	—	—	—	1.90	—	1.90	—
Power consumed by motor	kW	1.860	1.860	1.710	1.540	1.530	1.500	1.500	1.530	1.580	1.600	0	0	1.510	1.400	1.560	0	0	0	0	1.550	0	1.570	0
„ „ by heating	kW	3.650	0	1.390	3.590	3.600	4.000	4.600	3.040	3.530	3.040	1.175	3.750	4.220	8.630	3.900	2.700	3.770	4.810	8.780	3.920	4.220	3.890	4.160
„ „ in all	kW	5.510	1.860	3.100	5.130	5.130	5.500	6.100	4.570	5.110	4 640	1.175	3.750	5.730	10.030	5.460	2.700	3.770	4.810	8.780	5.470	4.220	5.460	4.160
Barometric press. in mm Mercury	B	725	719	731	725	725	731	724	724	729	729	729	730	716	723	715	721	721	731	723	721	721	723	723
Room temperature, in °C	t_{room}	15.0	14.5	15.2	14.0	15.1	15.0	14.5	14.5	14.5	15.2	14.3	14.7	13.9	15.0	12.0	13.5	14.1	14.8	14.4	12.0	11.2	12.2	12.0
Temperature at outer surface of heating tube: below	t_4	37.0	25.0	30.2	36.0	35.7	39.0	40.0	34.5	28.2	24.0	17.0	18.5	38.8	52.1	24.5	20.5	23.0	26.5	39.0	35.0	22.0	34.2	20.0
450 mm above t_4	$t_{4\,1/2}$																							
in the middle	t_5	36.8	2.40	29.0	35.1	35.3	37.6	39.2	34.2	32.5	29.9	21.0	31.6	40.8	57.0	47.0	35.0	40.6	47.7	65.9	36.3	39.2	35.8	38.2
above	t_6	37.8	24.8	31.5	38.7	40.0	41.5	43.4	38.0	43.5	46.0	38.0	65.3	40.2	57.6	47.4	38.4	44.2	51.4	65.8	36.4	42.0	35.5	42.2
Temperature of air at a distance of 0.5 metres: below	t_7	16.0	14.8	16.3	15.0	16.0	16.1	15.0	15.0	15.0	15.5	14.5	15.0	15.0	16.9	13.0	14.0	15.0	15.4	16.0	13.0	11.6	13.2	13.0
in the middle	t_8	16.8	16.0	17.0	16.2	17.0	17.4	16.2	16.0	16.2	16.9	15.4	16.2	15.9	18.0	14.0	15.9	16.5	17.2	17.9	13.8	13.0	14.1	14.6
above	t_9	17.1	16.4	17.2	16.8	17.4	17.8	16.6	16.4	16.8	17.5	16.0	17.3	16.2	18.2	14.6	16.5	17.0	17.8	18.3	14.0	13.2	14.5	15.0
Average val. for heating pipe (graph.)	t_m	37.2	24.6	30.2	36.7	37.6	39.3	40.9	35.5	34.2	33.3	24.0	35.5	39.9	55.6	41.3	32.8	37.6	44.1	58.2	35.9	36.1	35 5	35.7
$t_m - t_{room}$	Δt_h	22.2	10.1	15.0	22.7	22.5	24.3	26.4	21.0	19.7	18.1	9.7	20.8	26.0	40.6	29.3	19.3	23.5	29.3	43.8	23.9	24.9	23.3	23.7
$t_2 - t_{room}$	Δt_p	29.3	14.8	21.0	31.4	31.5	33.1	36.0	29.3	28.0	22.7	—	—	34.5	50.6	26.6	—	—	—	—	32.1	—	30.8	—
$t_3 - t_{room}$	Δt_k	29.5	14.5	21.7	33.4	33.5	35.8	38.3	32.3	38.9	40.3	31.7	66.0	37.8	57.4	49.0	33.3	40.5	48.7	70.1	35.0	42.2	33.7	40.2
KW radiated by heating pipe	L_h	0.866	0.369	0.563	0.888	0.880	0.959	1.053	0.814	0.758	0.690	0.354	0.805	1.034	1.737	1.185	0.742	0.925	1.185	1.906	0.941	0.986	0.914	0.933
motor, pump, meter,	L_p	1.135	0.655	0.844	1.214	1.219	1.282	1.399	1.135	1.086	0.901	0	0	1.337	2.069	1.035	0	0	0	0	1.242	0	1.191	0
pipe connections	L_k	3.509	0.836	1.693	3.028	3.031	3.259	3.648	2.621	3.266	3.049	0.821	2.945	3.359	6.224	3.240	1.958	2.845	3.625	6.874	3.287	3.234	3.355	3.227
cm² per watt	f_k	66.1	278	137	76.6	76.6	71.2	63.6	88 3	71 0	76.1	282	78.6	69.2	37.2	71.6	118.5	81.4	64.0	33.7	70 6	71.6	69.1	71.8
cm² per watt	f_h	40.4	94.8	62.1	39.4	39.8	36.5	33.2	43.0	46.1	50.7	98.8	43.5	33.9	20.15	29.5	47.1	37.8	29.5	18 37	37.2	35.5	38.3	37.5
		Heating coil in upper part of pipe												Heating coil in lower part of pipe										

The values derived from this formula are contained in Table II. The quantity f_k is represented graphically in Fig. 4, as a function of the maximum oil temperature or excess temperature of oil above room temperature $t_3 - t_{room} = \Delta t_k$. The curves obtained, for constant quantities of oil, correspond fairly exactly to the expression $f_k = k/t_k^{1.5}$. k is a constant for each quantity of oil. In the case of variable quantities of oil, the test results give us approximately the following formula: –

$$f_k = \frac{k'}{(\Delta t_k)^{1.5} \times (v+a)^n} \quad \text{or}$$

7) $\log(f_k) = 4.62288 - 1.5 \times \log(\Delta t_k) - 0.272 \times \log(v + 3.22)$.

The curves (a) in Fig. 4 are based on the equation 7). These values of f_k apply to the case where the screen is removed, and the air can circulate freely round the cooler; they are about 14 % smaller than when the screen is fitted. We can also obtain a similar value f_h for the heating pipe, viz:

8) $$f_h = \frac{35000}{(L_h)\,KW \times 1000}\ \text{cm}^2/\text{watt}.$$

The values derived from this formula are also included in Table III. It will be noted that f_h is nearly half as small as f_k. The present tests show that the arrangement adopted for the cooling system in question does not represent the most favourable solution of the problem. The reason for the high values of f_k resides in the fact that the tubes are disposed too close together for the given length of tube; consequently, the rising air has to overcome too great a resistance, with the result that it can only flow slowly and gets very hot.

In the case of test 14, for instance, where the maximum excess temperature of oil above room temperature $\Delta t_k = t_3 - t_{room}$ was 37.8° C, the escaping air had a temperature of 47° C, for a room temperature of 13.9° C. There was thus between the incoming oil at 37.8° + 13.9° = 51.7° C and the escaping air at 47° C a temperature drop of 51.7° — 47° = 4.7° C.

It is clear that, under such conditions, the cooler works in an uneconomical way. Tests were also carried out with a view to determining the distribution of the air above the cooler. A test with smoke showed that the air from below passed immediately into the centre of the stack and escaped at the top. The value obtained during test 8 for the velocity of air between the tubes was about .7 m. per sec.

It was not possible, with this cooler, to carry out accurate investigations with regard to the individual values of temperature drop between oil and metallic wall, or between metallic wall and air, as, owing to the low velocity of air, the inner parts of stack were cooled much less energetically than the outer parts, where the air could flow unobstructed.

The metal temperature of the outer tubes and the temperature of air flowing past them could, however, also be measured. The values obtained are contained in Table III. If we now assume that the temperature of the oil flowing out of the cooler is given approximately by the average measured temperature t_1, we obtain, for the test 14, the values of pressure drop plotted in Fig. 5. The ratio between the values of pressure drop at the inlet of oil into cooler, in the case of one of the outer angle tubes of cooler, is, according to Fig. 5:

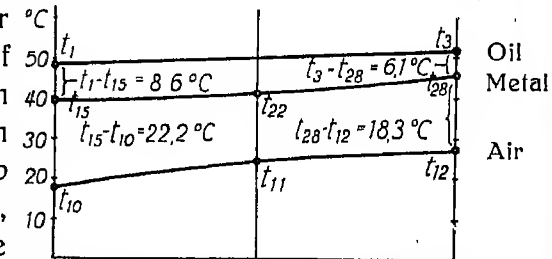


Fig. 5. Values of temperature drop during test 14.

$$\frac{\text{Temperature drop oil-metal}}{\text{Temperature drop metal-air}} = \frac{t_3 - t_{28}}{t_{28} - t_{12}} = \frac{6.1}{18.3} = \frac{1}{3}.$$

Recapitulation.

1) The cooler was tested at different oil temperatures and with different quantities of oil, with and without screen, and the value f_k = a cm²/watt ascertained for the whole cooler.

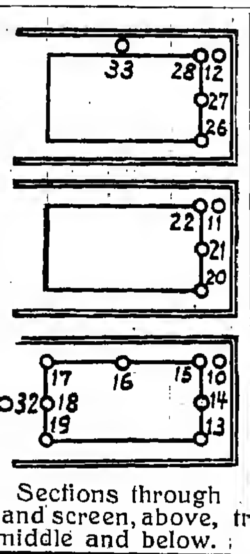
2) No accurate data could be obtained regarding the individual values of temperature drop between oil and metal and between metal and air, as the oil, metal and air temperatures, in the case of the inner tubes, could not be measured.

3) The tests with natural oil circulation cannot be generalised without further investigation, as the results depend entirely upon whether the source of heat is in the upper or lower part of heating tube.

Further tests are to be carried out with a cooler of same length but consisting of oval tubes such as will permit of wider air passages, so that the air will be able to circulate through the inner parts of stack without encountering so great a resistance as in the present case. Tests will also be made with a cooler having two concentric tubes.

Table III

	with screen																			without the left side		without screen	
Test №	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
t_3†	44.5	29.0	36.9	47.4	48.6	50.8	52.8	46.8	53.4	55.5	46.0	80.7	51.7	72.4	61.0	46.8	54.6	63.5	84 5	47.0	53.4	45.9	52.2
t_{33}	26.0	23.0	34.0	32.3	36.0	42.5	36.0	32.2	32.3	44.2	34.0	52.6	47.0	65.0	49.0	39.5	46.4	53.2	71.0	40.6	42.0	37.0	39.3
t_{12}*			23.8			26.9					21.8	26.0	27.3	34.0	26.0	23.6	25.5	28.1	35.7	22.9	24.1	19.8	19.8
t_{28}			31.2			42.8	45.0	39.8	44.0	45.0	33.5	54.5	45.6	62.8	50.8	37.6	43.8	50.8	71.8	40.0	43.2	38.5	42.0
t_{27}			31.6			42.6	45.5	40.4	42.3	43.3	31.9	53.0	44.2	60.3	45.7	36.0	42.1	49.2	65.4	40.0	40.0	37.5	37.6
t_{26}			30.5			39.5	47.1	41.0	45.2	46.0	32.0	49.0	40.0	55.0	41.5	35.2	41.0	47.0	61.0	40.5	44.0	37.0	40.5
t_{11}*			22.2			24.0						20.2	24.5	30.3	21.2	20.1	23.2	24.2	30.5	17.3	17.3	18.5	18.2
t_{22}			31.4			41.2	43.0	38.2	40.0	37.5	21.1	30.2	41.0		37.6	31.2	37.2	42.8		35.0	32.6	34.5	32.5
t_{21}			32.1			42.2	44.0	39.0	40.2	38.1	22.3	31.2	44.5	63.1	39.8	32.0	37.5	43.5	64.5	38.5	35.2	36.5	34.0
t_{20}			30.2			39.3	41.0	36.7	38.8	36.2	21.0	29.4	41.0	59.0	37.0	30.0	35.0	40.6	60.2	36.5	34.0	35.0	33.0
t_{10}*			18.0			17.5						16.2	17.6	21.0	14.5	14.8	15.8	17.0	19.2	21.0	17.4	18.0	15.0
t_{10}			29.0			39.0	40.9	35.5	33.5	28.2	16.6	19.9	39.2	55.0	27.2	23.2	27.0	32.1	47.2	35.8	26.2	33.6	24.5
t_{18}			27.8			35.2	40.8	35.2	33.2	28.0	16.0	18.8	38.4	54.0	26.8	22.0	25.7	30.5	46.0	35.2	25.3	34.0	24.9
t_{17}			28.9			39.0	41.0	35.6	34.0	28.3	16.2	19.3	39.3	55.0	27.0	23.1	27.1	32.3	48.0	35.5	25.5	34 2	25.0
t_{16}			31.4			41.9	43.3	37.2	35.3	29.2	18.0	21.4	41.6	57.8	29.1	24.6	28.5	33.1	49.0	35.9	26.2	35.8	26.2
t_{15}			29.5			39.0	41.0	36.0	34.3	28.8	17.2	20.6	39.8	54.8	28.6	24.3	27.8	32.2	47.3	35.0	26.5	32.5	25 4
t_{14}			30.9			41.2	43.5	38.0	36.8	30.5	17.6	21.2	41.7	57.1	30.2	25.2	29.1	34.1	50.1	37.5	28.2	36.2	27.8
t_{13}			30.5			40.5	42.4	37.1	35.4	29.3	17.5	21.0	41.0	56.2	29.5	24.7	28.5	33.2	48.0	37.2	27.9	35.6	26 7
t_1†	44.1	28.4	35.6	45.1	46.2	47.8	50 3	43.3	40.1	32.0	18.3	21.2	48.4	66.2	32.3	26.0	29.0	33.8	50.7	43.8	29.6	42.8	29.6
t_{32}	15.2	14.1	15.9	14.7	15.7	15.4	15.0	14.9	14.7	15.1	14.2	15.0	14.4	15.7	13.1	13.9	14 2	15.0	15.0	13.0	12.1		
t_{room}†	15.0	14.5	15.2	14.0	15.1	15.0	14.5	14.5	14.5	15.2	14.3	14.7	13.9	15.0	12.0	13.5	14.1	14.8	14.4	12.0	11.2	12.2	12.0
V†	154	35.3	32.2	36.6	36.4	33.3	37.3	22	7.6	4.00	—	—	30.7	32.0	3.93	—	—	—	—	30.6	—	31.15	—
	Heating coil in upper part of pipe												Heating coil in lower part of pipe										



t_{33}, t_{10}, t_{11} and t_{12} are at a distance of 20 mm from the tubes, t_{32} is 300 mm below the cooler in the path of the current of air.

Fig. 6. Sections through cooler and screen, above, in the middle and below.

*) Air temperature. † For meaning of notations, see Table II.

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OERLIKON

Electric Goods Locomotives for the Swiss Federal Railways.

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At the present time, when railway electrification is being widely advocated as the panacea for many of the existing evils of our transport system and a committee appointed by the Government is considering, amongst other kindred problems, the merits of the rival systems—the high-voltage direct-current system and the alternating-current system—the following particulars of developments on the single-phase system of the Swiss Federal Railways should prove of considerable interest. In March, 1918, the general management of the Swiss Federal Railways ordered from the Ateliers de Construction Oerlikon, together with the Swiss Locomotive Works, Winterthur, ten of the first electric locomotives of the 2-6-6-2 type for goods service on the Gotthard line. Further orders for twenty-three similar locomotives followed in the spring and autumn of 1919 and the spring of 1920. In the meantime, the delivery of the first ten locomotives is already completed. For the goods service on the Lucerne-Chiasso section—formerly the Gotthard Railway—the locomotives ordered are required to haul a train of 860 tons between Goldau-Chiasso, making two journeys in twenty-eight hours, with a stop at each terminus of 15 min. On inclines above 1 in 100 the trains are assisted by a banking locomotive. On the section Chiasso-Bellinzona, the train weight for one locomotive is reduced to 625 tons. During the whole time of the above-mentioned service, the temperature of the main electrical equipment must not exceed that given by the Standard American Rules. On an incline of 1 in 38 a train weight of 430 tons has to be hauled at a speed of 22 miles per hour, and 300 tons at 31 miles per hour, this latter weight must also be hauled at a speed of 40 miles per hour on an incline of 1 in 100. Further, the locomotives must give on an incline of 1 in 38 for 15 min. an output increased by 20 per cent., *i.e.*, either by increasing the speeds or loads or by a combination of both.

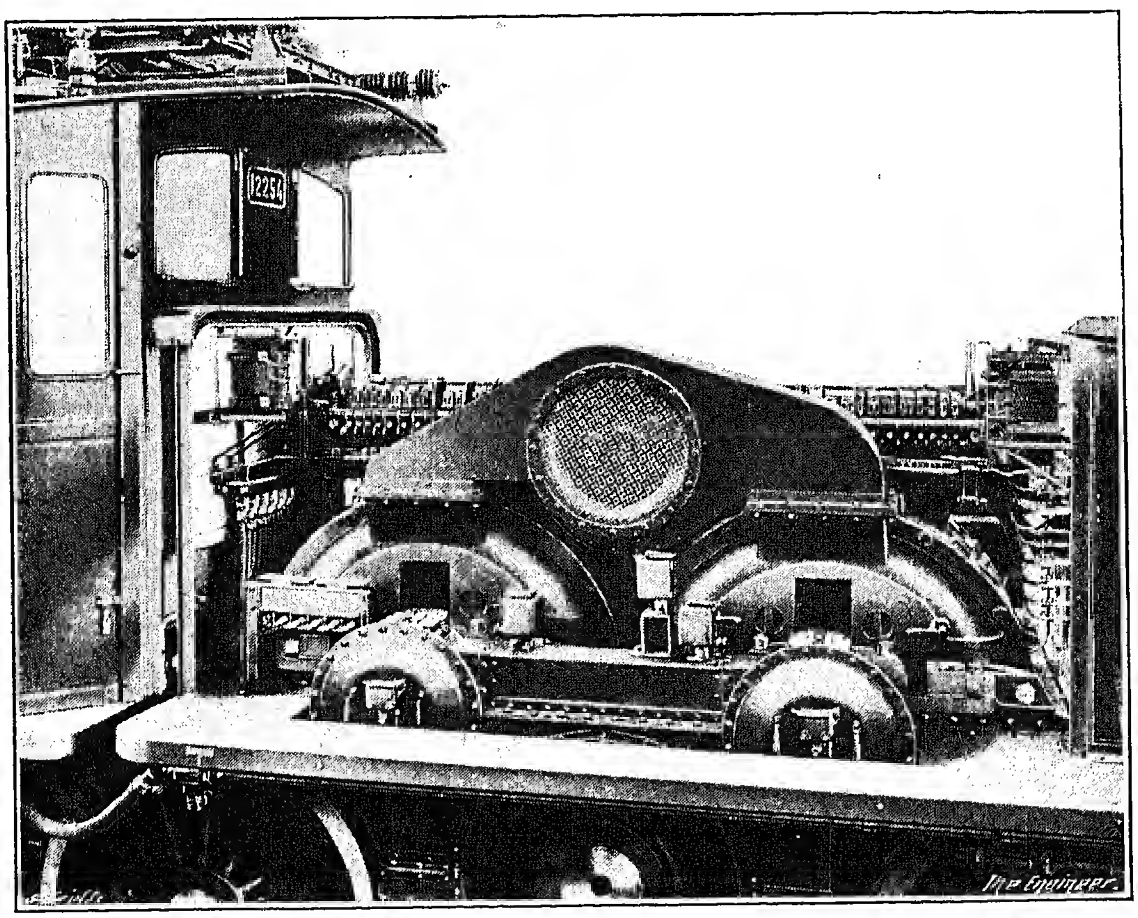


FIG. 1—DRIVING MOTORS IN POSITION

The starting effort demanded is that the locomotive must be able to start a train on a 1 in 38 gradient, with a weight of 430 or 300 tons, and accelerate in 4 min. to a speed of 22 or 31 miles per hour respectively. The maximum speed of 40 miles per hour of

which these locomotives are capable when hauling a 300-ton load up a gradient of 1 in 100, enables them to be used for passenger and express trains on the mountain section of the railways. Some further particulars regarding the track, overhead line and the locomotives are given in the Supplement attached at the end, showing the general arrangement of the locomotives, which we will now proceed to describe in detail.

Mechanical Part.

As already indicated by the type, the locomotive is composed of two bogies, with three coupled driving axles and one trailer axle. To allow of easy running round curves, the centre driving axle of each bogie has 1in. side play, and the trailer axles, which are carried on Bissel frames and have a lateral play of 3¼in. each, are normally maintained in the central position by means of leaf springs. The springing of the bogie frames on the axles is of the usual construction. For the purpose of equalising the pressures on the axles, the supporting springs of the first axle are connected by means of equalising bars with the trailer axle on one side and to the second driving axle on the other. The two bogie frames are identical and interchangeable in their construction, which would appear to be a great advantage, both from a technical point of view, and in regard to the erection and maintenance of the electrical and mechanical equipment. The low protecting covering over the electrical apparatus is easily taken down, thus facilitating the removal of the motors and giving easy access for inspection and repairs. The bogie frames are connected by a strong short coupling, which has a leaf spring inserted. This coupling transmits the tractive efforts from one frame to the other. The four motors are firmly fixed in pairs to the frames between the first and second driving axles. The power is transmitted from each pair of motors to a common slow-speed shaft carried in the frame by means of gearing on each side, having a ratio of 4.03 to 1. The drive is transmitted from the crank pins at each end of the slow-speed shaft to the driving wheels by means of connecting-rods coupled to the crank of a jack shaft. The first driving wheels are driven from slide bearings on the connecting-rods, while the other two pairs of driving wheels are connected thereto by means of coupling rods. The connecting-rod may be considered to represent an inverted driving triangle with the slide bearing as its apex, but power is only transmitted by the motors to one instead of two corners of the base. To allow for the necessary elasticity in the drive, the jack shaft is suspended from the frame by means of spring and link motion, which permits a definite horizontal movement. All driving wheels are fitted with two brake blocks, which are operated either by means of the usual hand brake or by double-acting Westinghouse air brakes. Each bogie is fitted with a 15in.

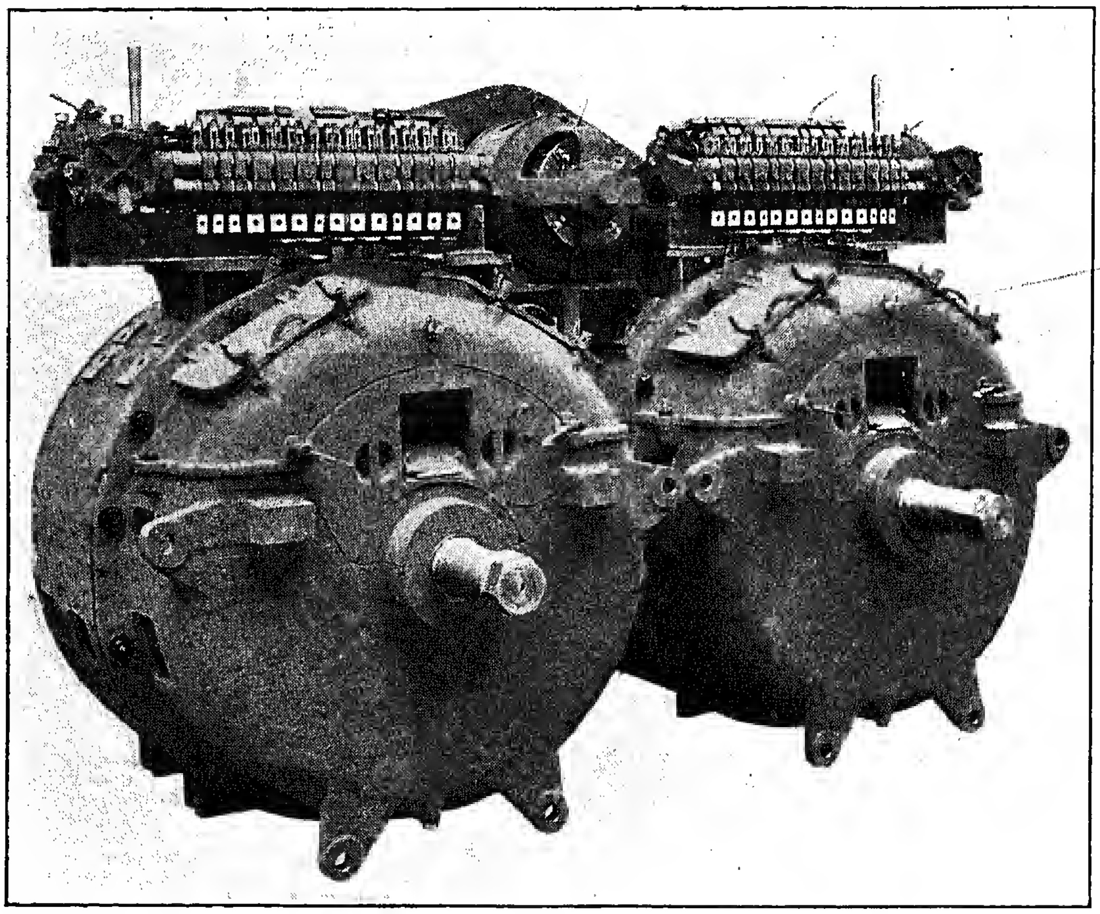


FIG. 2—DRIVING MOTORS REMOVED

brake cylinder. With the air brake, a maximum of 80 per cent. of the total adhesive weight of the locomotive is possible, and with the hand brake, which only affects one bogie, 90 per cent. of the adhesive

in three parts, the two end parts being fitted to the bogies, which support also either end of the middle portion. The electrical apparatus fixed in the end portions of the locomotive has only a low sheet iron covering

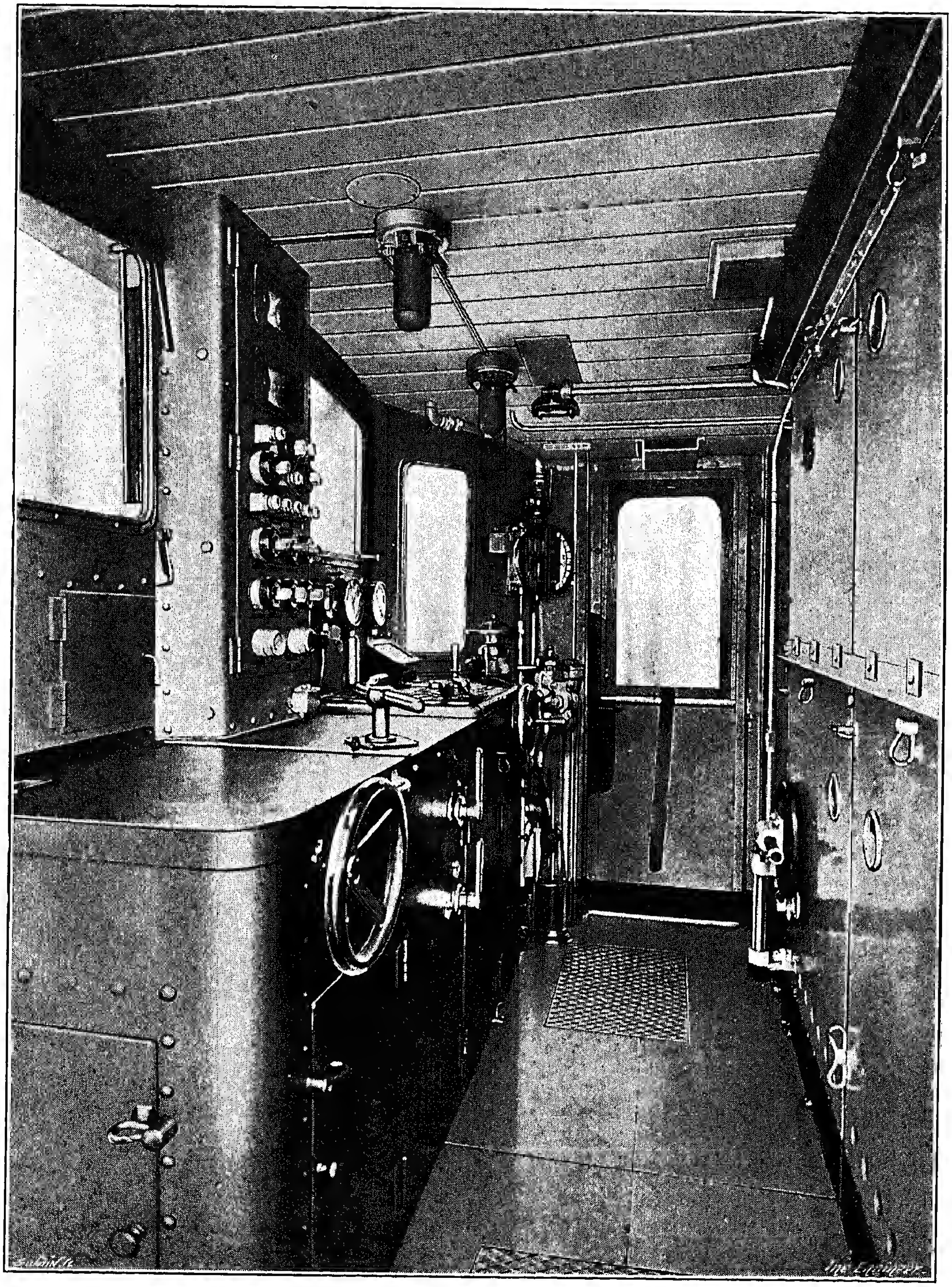


FIG. 3—INTERIOR OF DRIVER'S CAB

weight of that bogie is obtained. Four sanding boxes are fitted to each bogie.

Four views of the locomotive, in one of which it is compared with other Oerlikon locomotives in service, are shown on pages 8 and 9. The locomotive body is fitted, the centre portion being left free to take the short locomotive body, which chiefly contains the transformer, drivers' stands, &c. It is claimed that this method of construction has advantages compared with others in that the short body can be of very

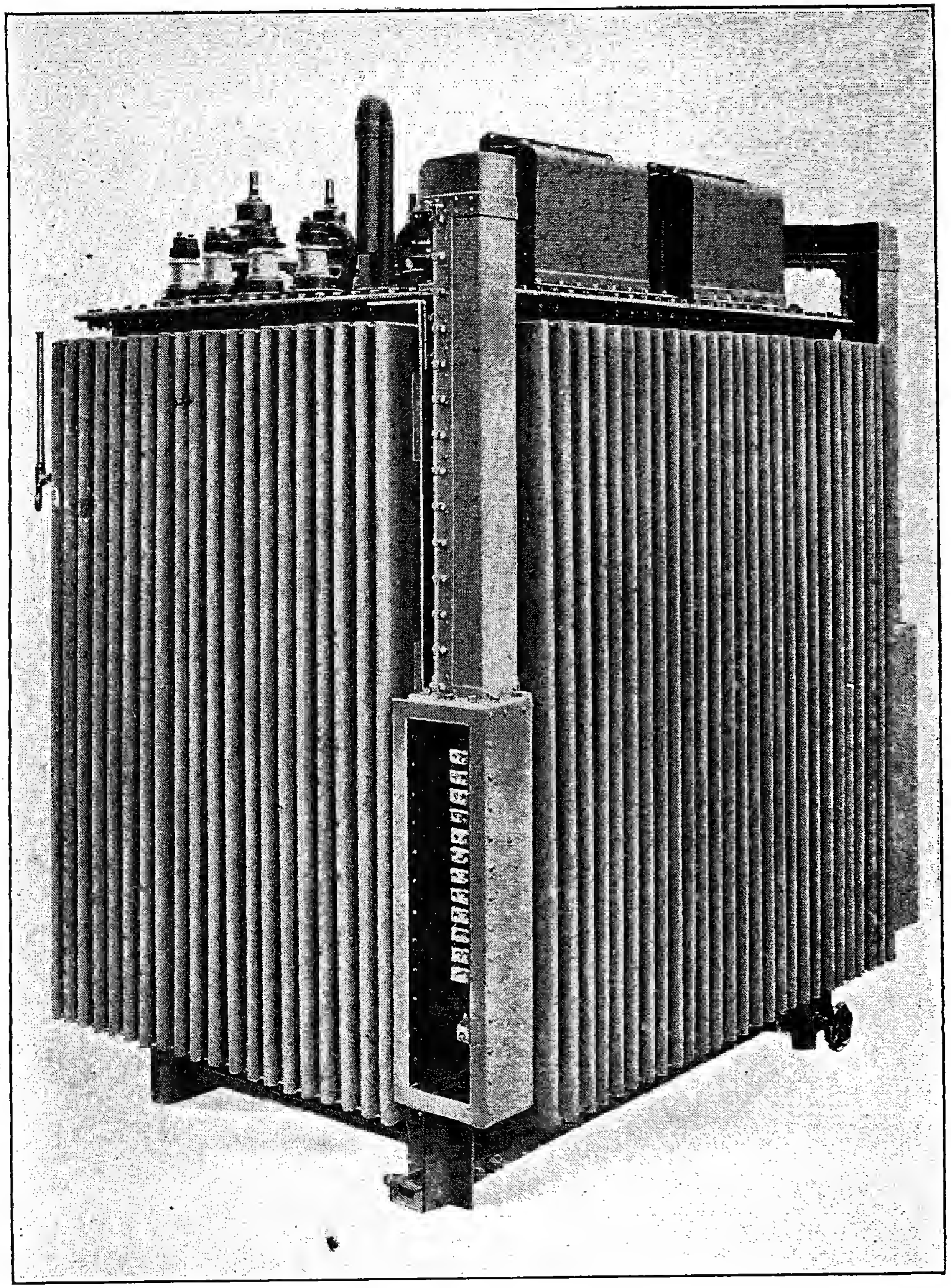


FIG. 4—OIL-COOLED STEP-TRANSFORMER

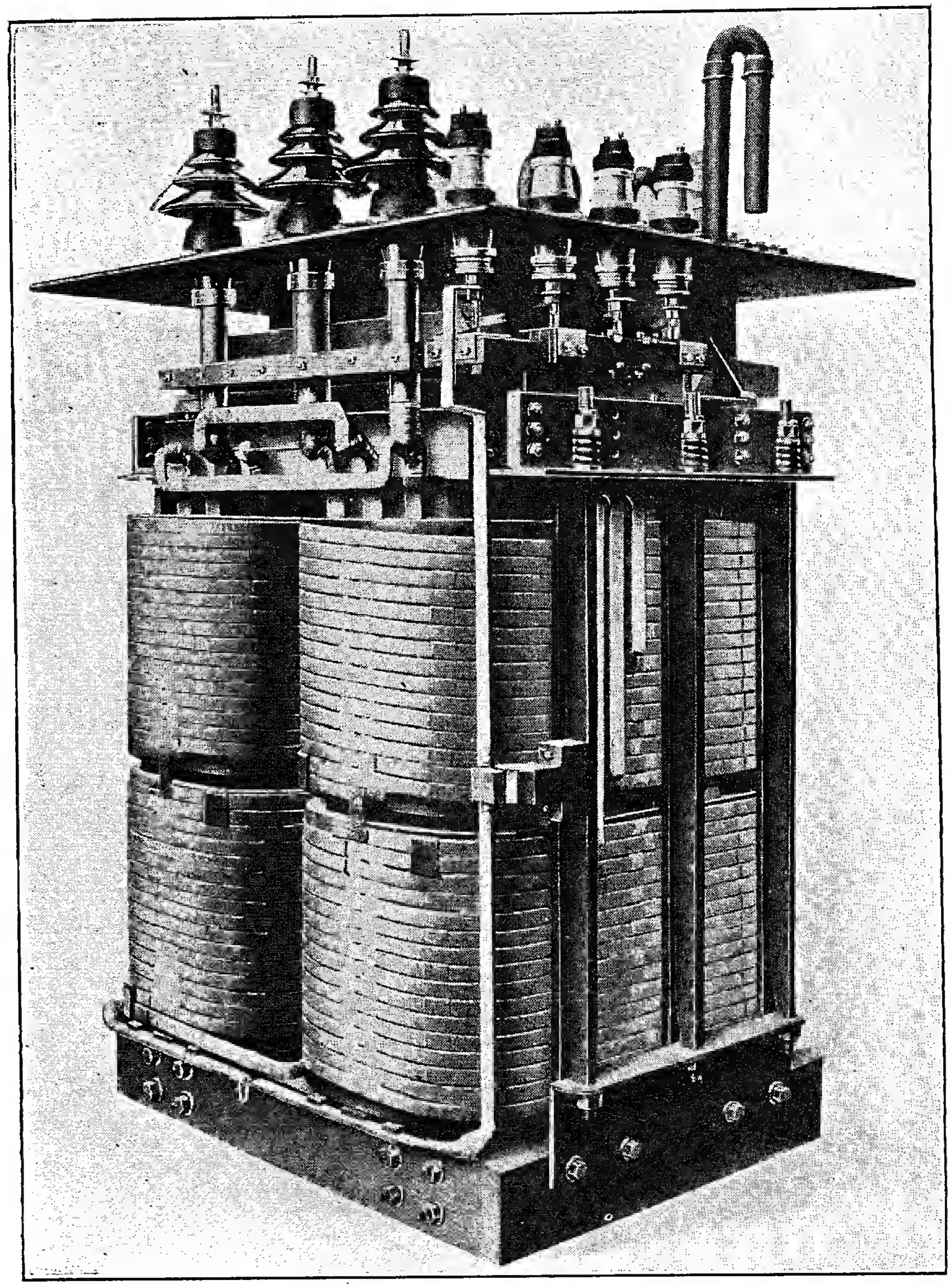


FIG. 5—STEP-TRANSFORMER WINDINGS

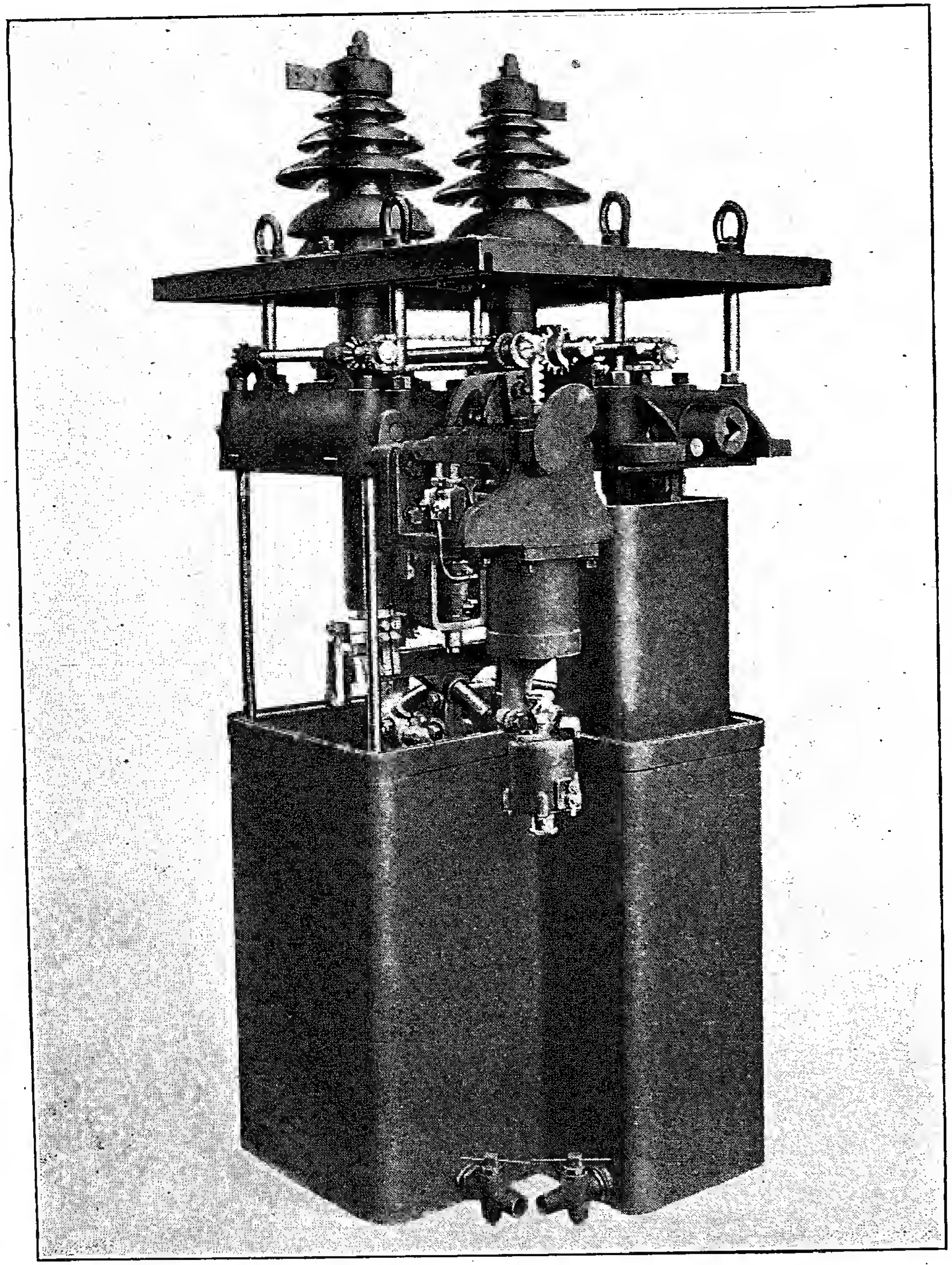


FIG. 6—MAIN OIL SWITCH

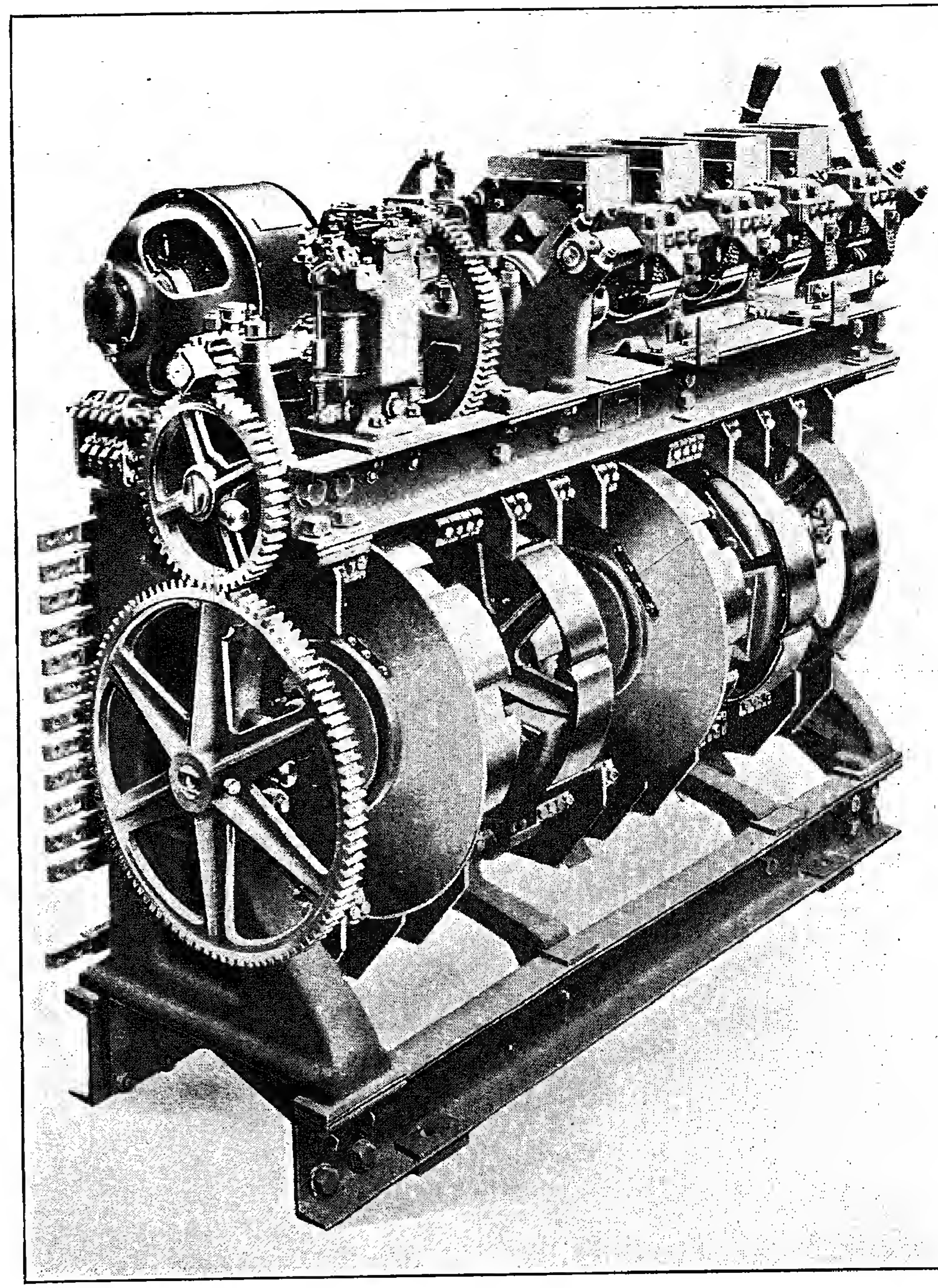


FIG. 7—STEP SWITCH WITH MOTOR-OPERATED CONTACT DRUM

rigid and heavy construction, and, owing to its short length, all tendency to spring is eliminated. To prevent the ingress of snow and rain, the centre portion overlaps the two end coverings; this also gives the locomotive a pleasing and continuous appearance. The driver has a free and uninterrupted view of the track in spite of the end sections of the locomotive, and has a certain sense of personal safety, owing to their being in front of him. The short body rests on each bogie on a pivot, and additional spring supports on each side of the pivot. One pivot is a fixture on the connecting girder between the bogies, the other has a certain amount of end play, so that no tractive strains are transmitted to the body. The end covers are provided with the necessary inspection doors at the top and sides. The air required for cooling the motors is drawn in by fans through pneumatically regulated louvres in the end covers, and to prevent ingress of brake dust, sliding covers are fitted underneath. A ladder, pneumatically interlocked with the current collectors, permits of access to the roof and the collectors. In each driver's cab —Fig. 3—are fitted the air pressure gauges and Hasler speedometers and all the necessary controls for the locomotive.

Electrical Part.

In general, the arrangement of the electrical apparatus is similar to that of the express passenger locomotives of the 2–4–4–2 type already supplied to the Swiss Federal Railways. In the centre of the locomotive is the oil-cooled step transformer, and arranged around this transformor are the main switch, a small converter and two-step switches for speed regulation. The four motors, as already mentioned, are mounted in pairs on each bogie underneath the end covers. The inspection of the motors is possible while running, through suitable openings inside the locomotive. On each pair of motors are mounted—as shown in Figs. 1 and 2—the reversers and the cooling fan; in front of them, but in a separate compartment, are mounted the switching choking coil, two resistances for the auxiliary poles of the motors, one brake choking coil and one air compressor.

The step transformer—shown in Figs. 4 and 5 on page 4—is of the vertical core oil-cooled type, con-

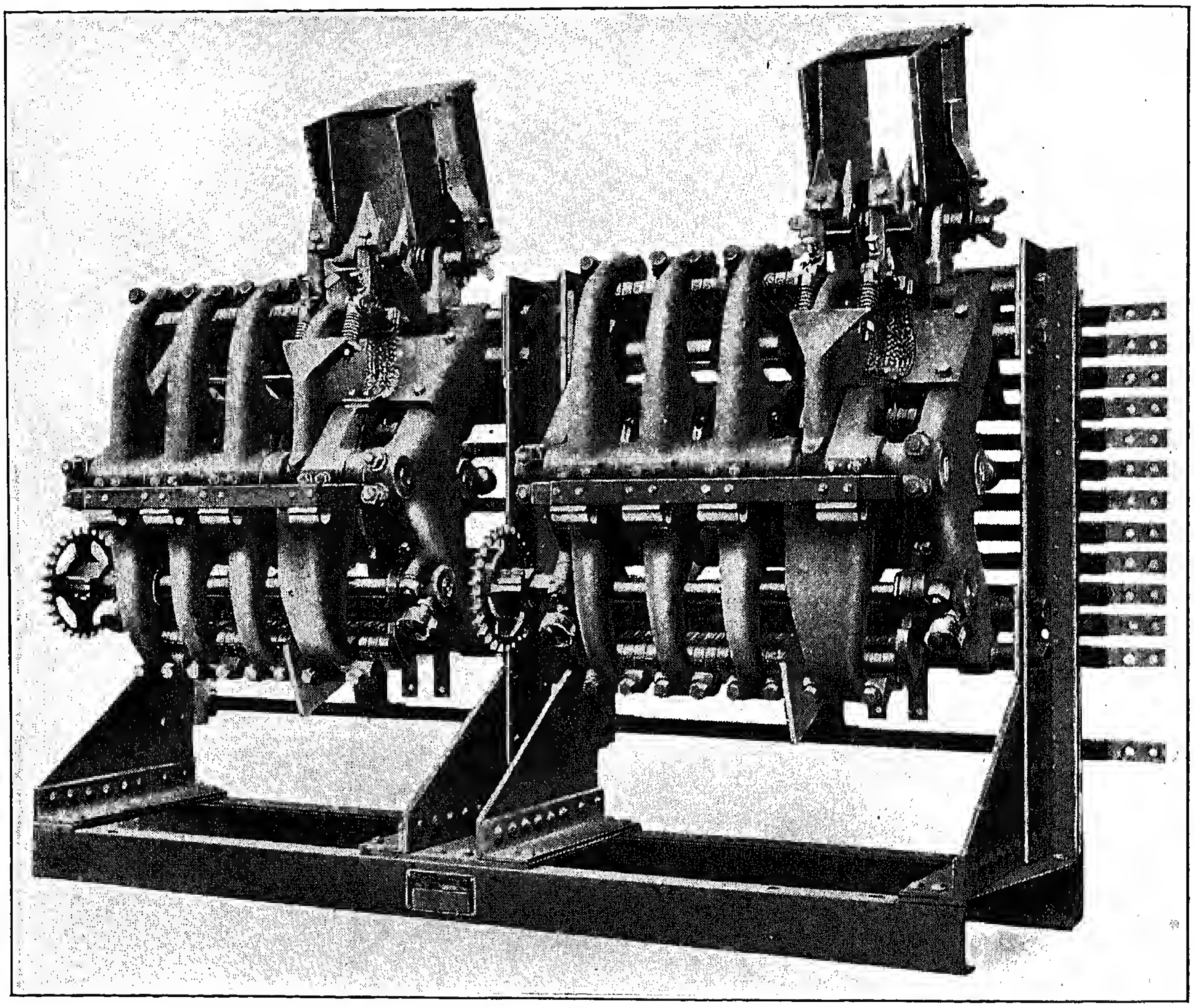


FIG. 8—STEP SWITCH WITH CONTACT LEVERS FOR HAND OPERATION

structed for outdoor operation, and is placed in a draught tube or chimney, open at the top to the air, its cover forming part of the locomotive roof. This construction is advocated as more advantageous than that of the usual type of locomotive transformers, in that the heat is conducted direct to the atmosphere outside the locomotive cab, thus not affecting the interior. To remove the transformer, it is unnecessary to dismount any of the apparatus, and it can be removed when the pantograph collector is in the highest position. The cooling of the oil tank is assisted by two ventilating fans, which force air in at the bottom of the transformer chimney. By using an oil-cooled transformer, the ingress of brake dust, &c., is eliminated. The transformer is constructed for a primary pressure of 15,000 or 7500 volts and a

The secondary winding for the motors contains two separate sections, each with twenty-one tappings brought out through the transformer case on the respective sides, twelve of these tappings being connected to the step switches. The two sections are normally in series and wound for a maximum pressure of 567 volts, the complete winding being earthed at the connection between the two parts. The heating winding is arranged for a maximum pressure of 1180 volts, and is provided with two tappings for 1000 volts and 800 volts respectively, so that the heating of the coaches can be easily regulated on the locomotive. The tappings are connected with a heating switch provided with an off position. This switch feeds through a current transformer for the ammeter and current relay to a single-pole oil switch. The

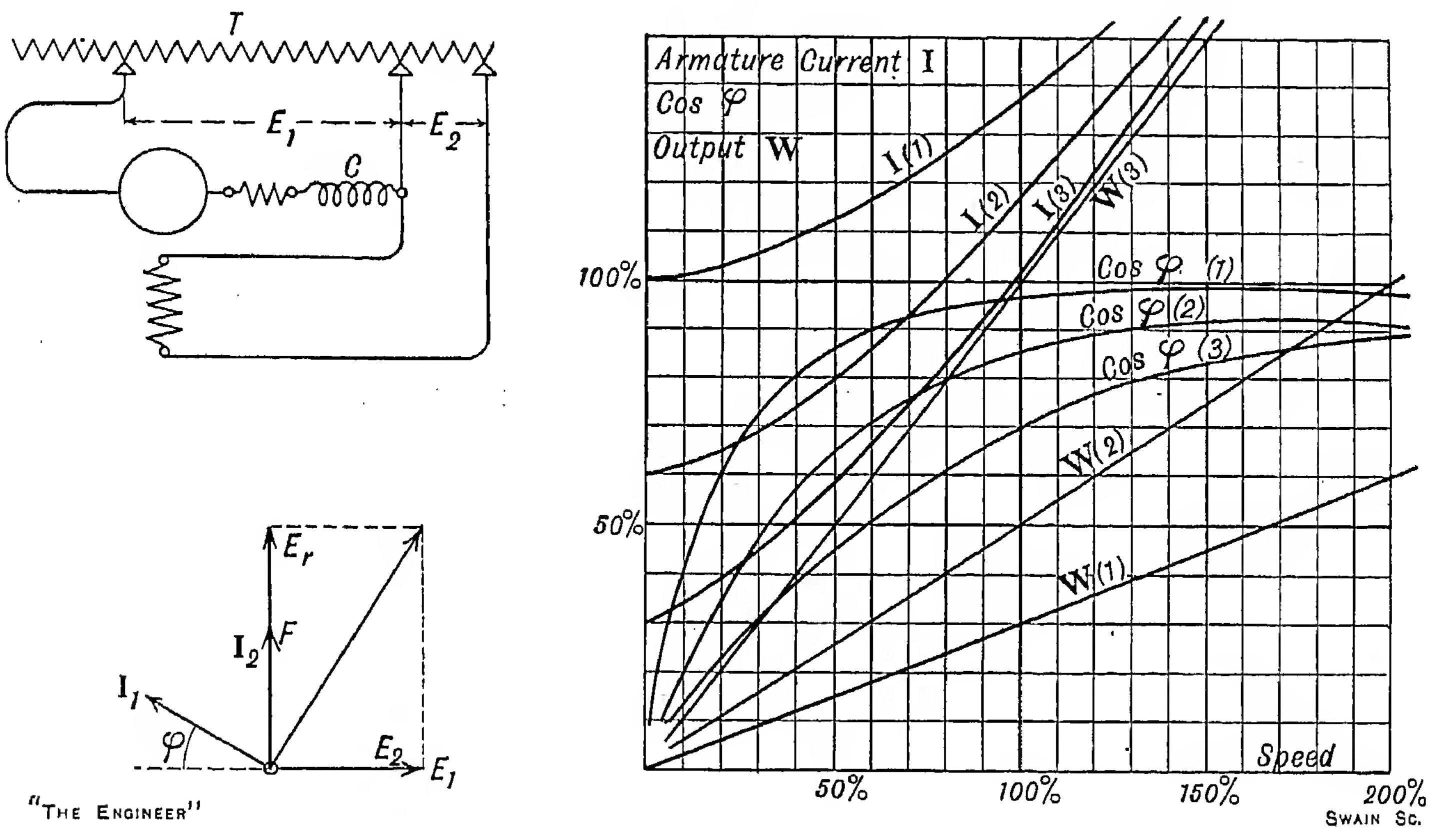
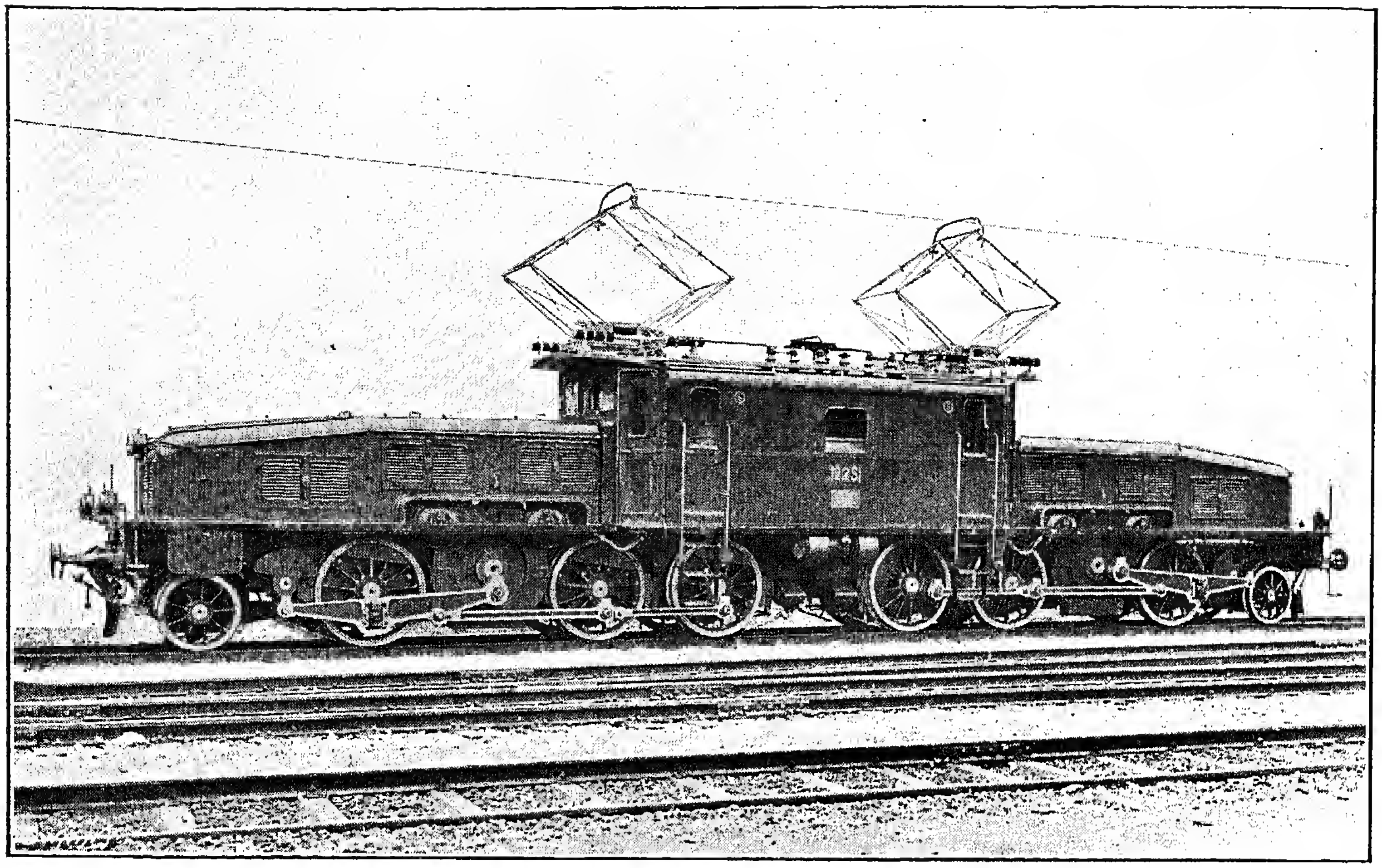


FIG. 9—REGENERATIVE BRAKING

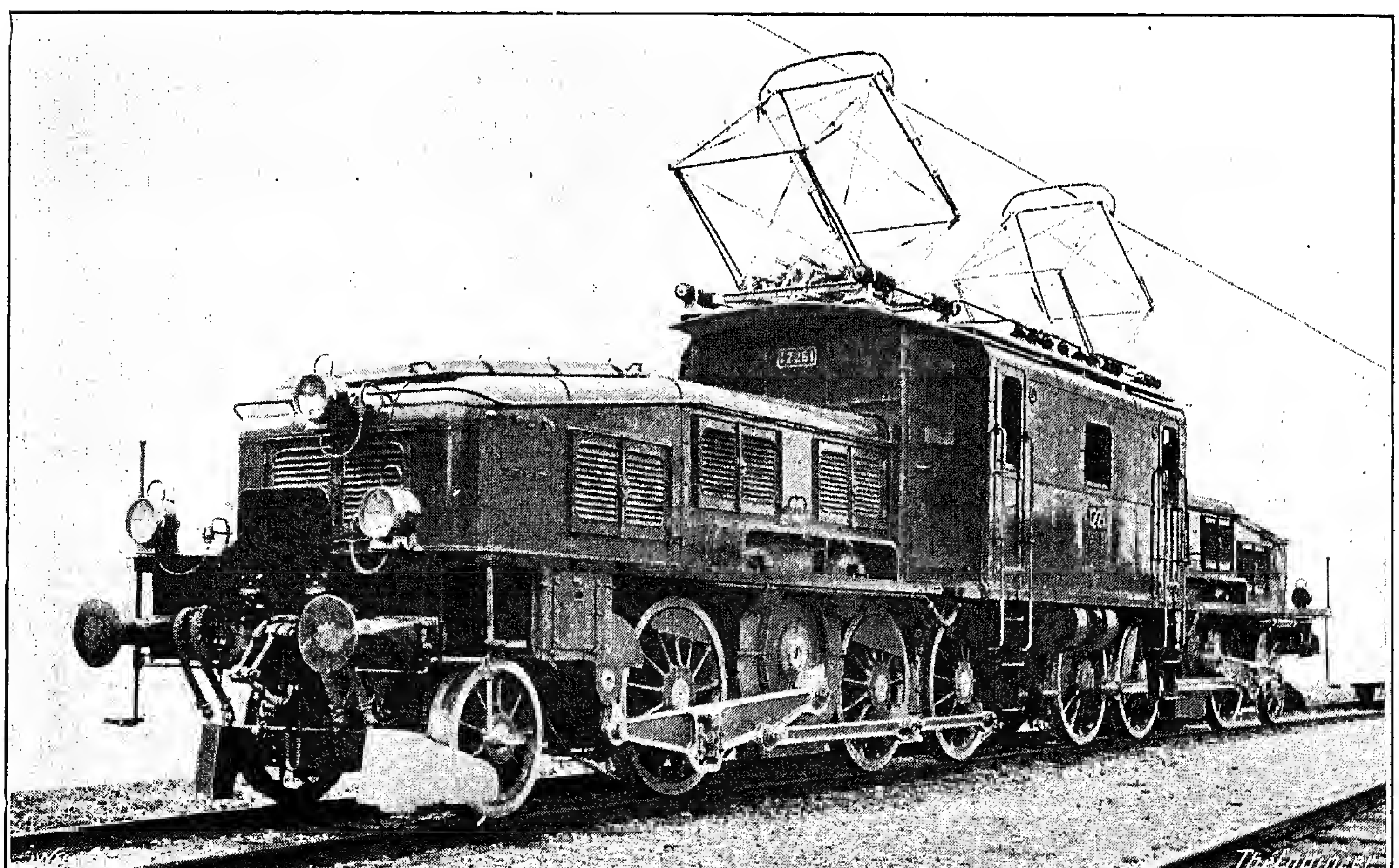
frequency of supply of 16⅔ cycles per second. Variations of pressure of from 5 per cent. above to 15 per cent. below normal are compensated for by suitably arranged pressure tappings, so that the normal output on the low-pressure side is maintained. Owing to the danger of flashing over of the line insulators due to smoke and soot, &c., during the operation of the line by steam and electric locomotives, the medium pressure of 7500 volts is at present used, and taking into consideration the connection of the motors, the primary windings are divided into four groups, two of which are always in parallel. The change over from one pressure to the other is made by changing the connections from the coils, which are brought outside the transformer for this purpose. Two independent secondary windings are provided, one for the motor circuits and the other for train-heating purposes.

change-over switch is interlocked with the oil switch, so that it can only be operated when there is no pressure and the oil switch is open. The oil switch feeds the heater circuits on the coaches, or, when steam-heated trains are being hauled, a special electrically heated steam boiler. The heater circuits are earthed to the rails at their respective coaches, while the windings for these circuits have a capacity of 400 kilowatts at 1000 volts and a maximum of 480 kilowatts at 1180 volts, the latter for the preliminary heating of the train before service when the transformers are not otherwise loaded.

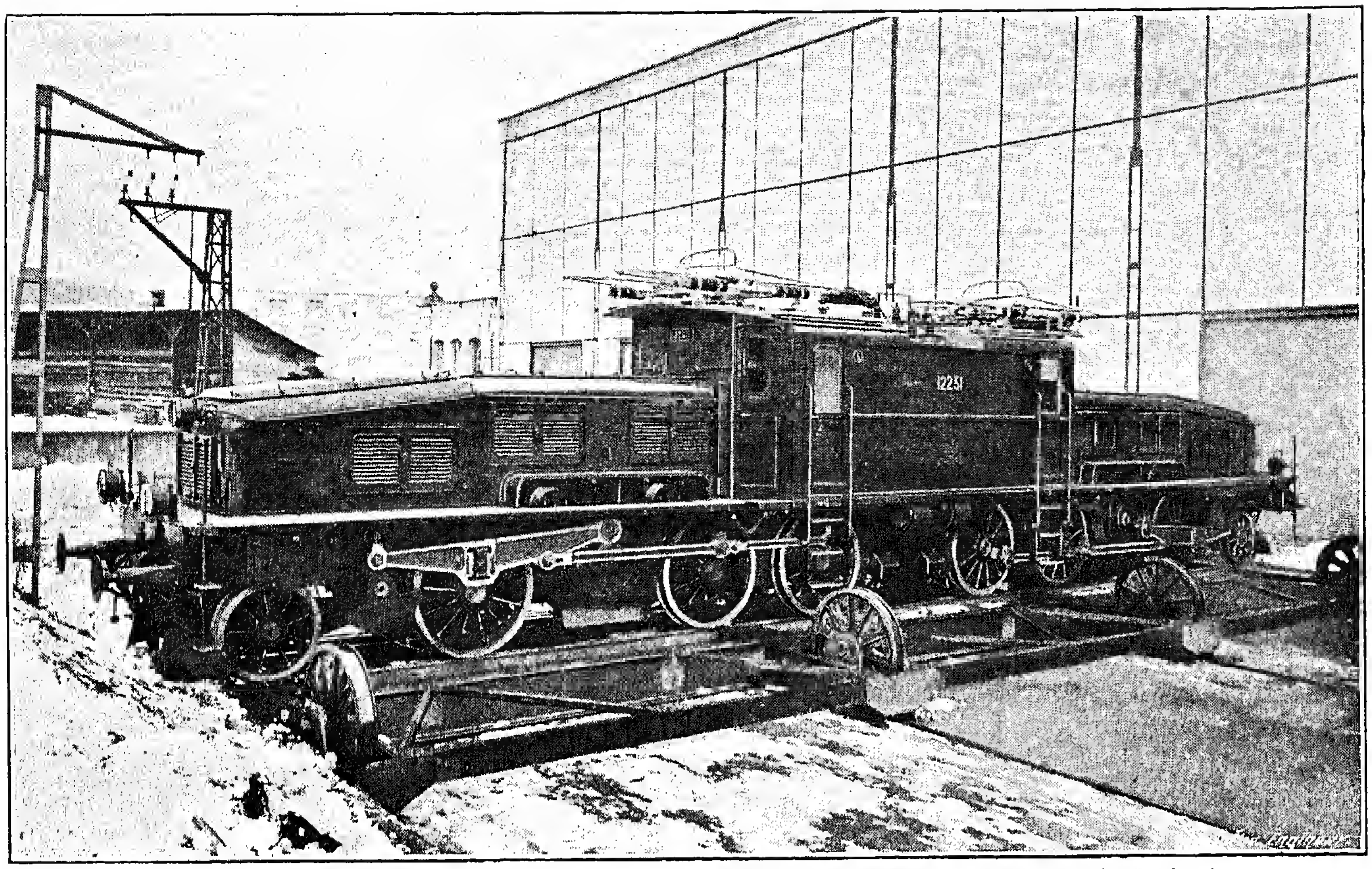
The main oil switch is so constructed that the cover forms part of the roof, and the earthing switch, usually outside the oil switch, is, on these locomotives, inside the oil switch case. There are therefore no cables or terminals inside the locomotives under line



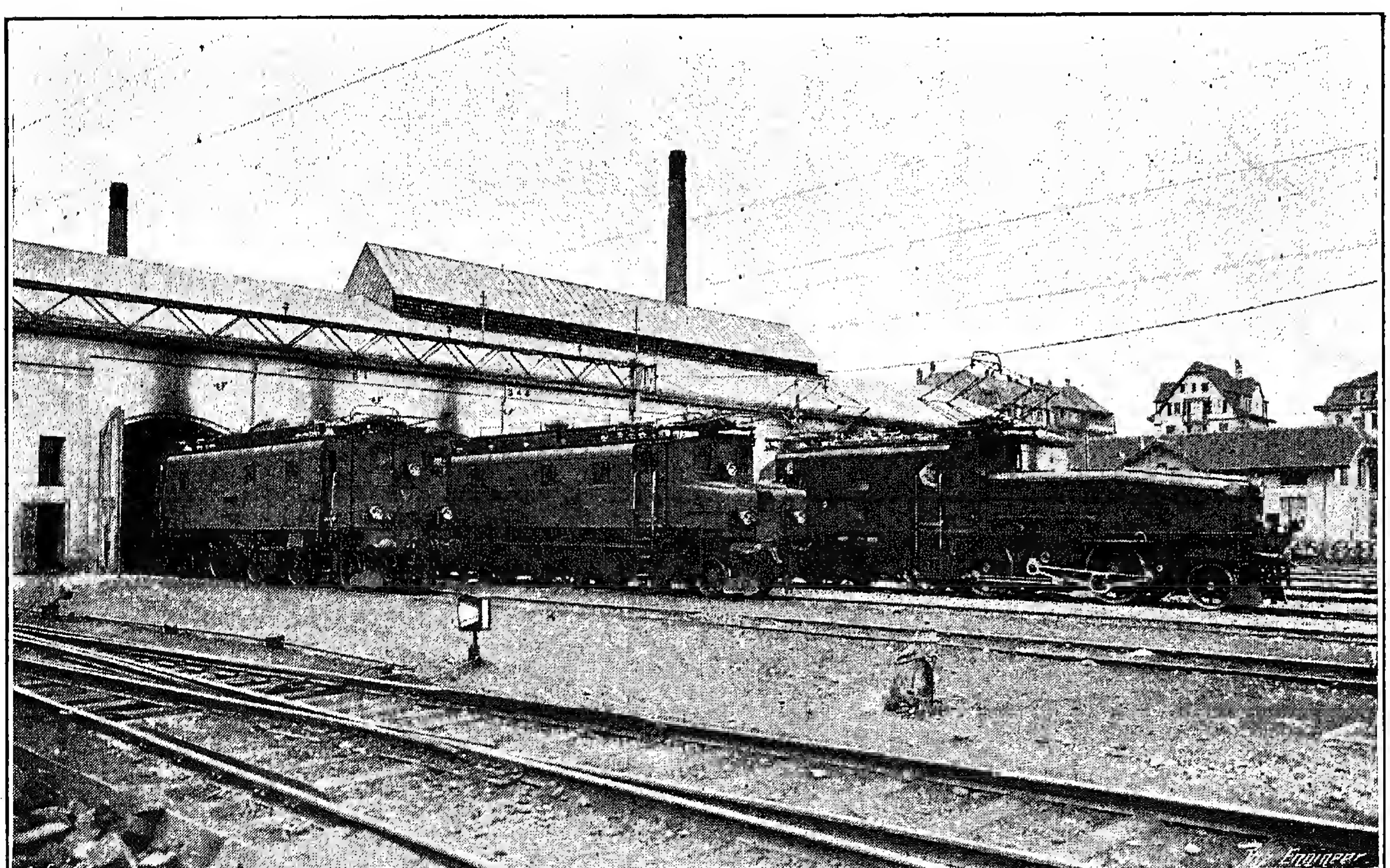
LOCOMOTIVE WITH CURRENT COLLECTORS IN RUNNING POSITION



PARTIAL END VIEW OF LOCOMOTIVE



LOCOMOTIVE WITH CURRENT COLLECTORS LOWERED



THREE TYPES OF ELECTRIC LOCOMOTIVES

pressure. In contradistinction to other methods of construction, there are no high-tension chambers on these locomotives, and the possibility of touching high-tension apparatus, &c., is therefore removed, the only precautionary measures being the interlocking of the main oil switch tank to prevent it being lowered while under pressure. This is accomplished by interconnecting the tank-lowering mechanism with the air valve controlling the pantograph collectors, so that the tank can only be lowered when there is no air pressure and the earth switch is closed. The switch is shown in Fig. 6 on page 5, with the tank lowered. In the circuit from the pantograph collectors are two knife switches. They are operated from inside the locomotive and are for the purpose of isolating a damaged pantograph collector from the high-tension circuit. The whole roof installation is subjected to a pressure test of four times the normal, *i.e.*, 60,000 volts, applied ten times for a duration of 30 sec. with 5 min. intervals, and with all normally earthed connections in place. The transformers are protected against sudden surges that would arise when switching on the full line pressure, by means of a damping resistance, which is first put in circuit and then cut out step by step. This switch can be operated from either driver's stand, being closed electro-pneumatically and opened electrically or by a hand-operated emergency release. The automatic release is effected indirectly by two overload relays in the motor circuit and one in the transformer circuit, also by a no-volt relay connected with the low-pressure side of the transformer. Furthermore, the switch can also be opened by a key. The switch is so constructed that it cannot be held closed on an overload or short circuit, even if the operating cylinder is still under pressure, or if the above-mentioned key is in the wrong position. The only protection on the locomotive against over-pressures for the electrical apparatus is an induction coil mounted on the cover of the transformer. Previous experience, it is stated, has shown that it is unnecessary to provide any elaborate or complicated protection devices on the locomotives, and that it is much better to equip the various sections of the overhead line with the necessary apparatus for protection against over-pressures.

The pantograph collectors, either of which can take the full-load current at a pressure of 15,000 and 7500

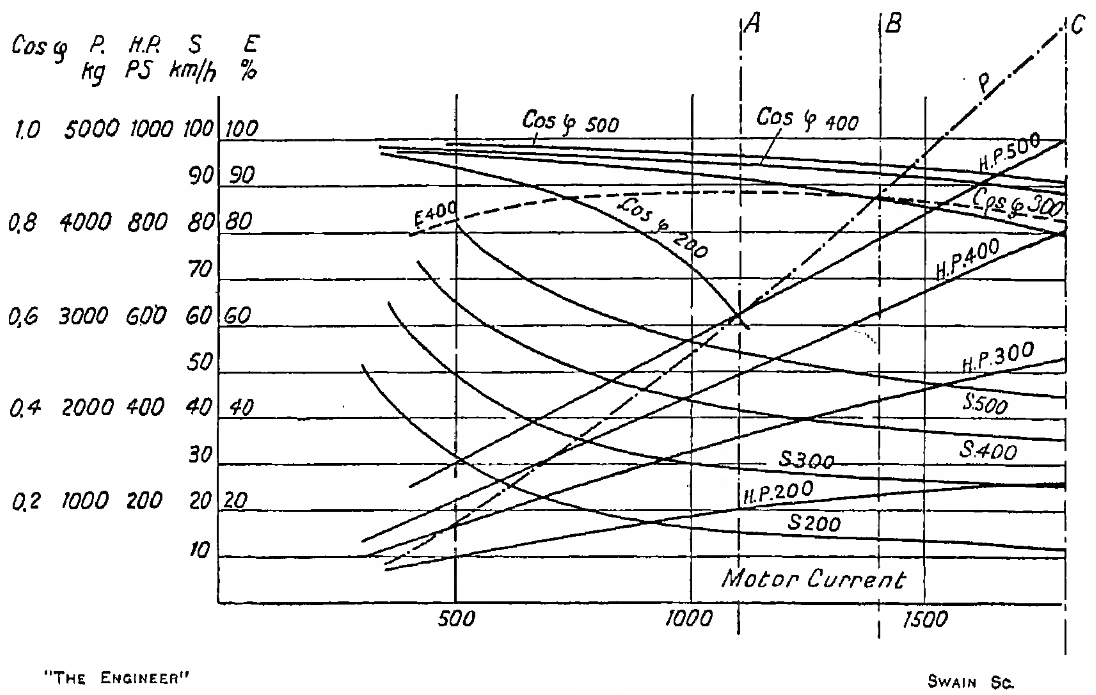


FIG. 10—MOTOR PERFORMANCE CURVES

volts, are operated by air pressure in order to ensure smooth and reliable working at all temperatures. The pressure of the collector bow against the overhead wire remains practically constant at any height of the wire above the rail level between 15ft. 9in. and 23ft. Both collectors can be operated from either driver's stand by means of air valves. For raising the collectors when there is insufficient pressure in the reservoirs, a hand-operated air pump connected with the pipes leading to the collector mechanism is provided, by means of which one collector can be raised in 30 sec. The novel design of the collector bow is worthy of special attention. By means of suitable supports, the centre about which the bow turns is brought a certain distance below the highest joint of the pantograph frame. By this means it is claimed that the effects of small irregularities in the height of the overhead line are greatly minimised, as the angle between the collector bow and line is larger than with the old form of construction, thereby giving a greater springing effect.

The motors, which are of the well-known standard construction of the Oerlikon Company, are semi-enclosed and of the compensated series type, with distributed field windings and auxiliary poles. There are no resistance connections between the commutator segments and the rotor winding: on the contrary, the connecting lugs between the two are liberally dimensioned to prevent heating effects. The twelve sets of brushes have five carbons each, 40 mm. wide and 9 mm. thick. The brush holders are mounted on a cast steel ring, which can be revolved

for the purpose of easy brush inspection and adjustment. The spring pressure on the brushes remains practically constant during the life of the brush, which amounts to about 60 per cent. of the total length. The stator slots are closed and the rotor slots semi-closed and skewed the distance of one slot width for the purpose of damping harmonic oscillations in the current and pressure waves. The motors have twelve poles, and with artificial cooling are capable of the following outputs at the wheel rims :—550 horse-power at 400 volts for the 1½ hour rating ; 425 horse-power at 380 volts continuously, the speed being 560 revolutions per minute. The characteristic curves for one motor working on a frequency of supply of 14.3 cycles per second are given in Fig. 10. The curves H.P. 200 and S 200 relate to the horse-power output of the motor and speed at the wheel rim in kilometres per hour for a pressure of 200 volts. Similar curves are given for other voltages. The curves marked E, P and cos φ relate to efficiency traction effort in kilogrammes at the wheel rim and power factor. The chain dotted lines A, B and C indicate the continuous, one hour and maximum current ratings of the motor. The speed control of the locomotives is performed by regulating the motor voltage through step switches in the usual manner. On these locomotives there are two mechanically different types of step switches, one for hand operation and one for electric motor control. The switching sequence for the main circuits is the same for both types. One is of the drum type—see Fig. 7 on page 5—as used for the Lötschberg locomotive, with the difference that the two drums are above one another, and that the servo motor only runs during switching operations, not continuously. The other type of switch—which is shown in Fig. 8—consists of a contact lever system operated by means of a cam shaft, with specially formed press contacts and a central blow-out arrangement. This type of step switch is designed for hand operation and eliminates the large physical effort usually required by the *personnel* when operating the previously known types. As previously stated, the reverser is arranged on the top of each motor, with two positions for running, two for braking and a zero position. The reversing switches are operated by compressed air apparatus, but they can also be operated by hand in case of emergency, the zero position being obtainable by hand only.

Regenerative Braking.

Electric braking has advantages over mechanical braking in that it practically eliminates brake block and tire wear and metallic dust from the brake shoes. These advantages increase with the weight hauled, and it has ever been the aim to brake the whole train weight on a down gradient by means of the locomotive which has hauled the train up the previous incline. In comparing the various current systems—direct current, three and single-phase—for electric railway operation, it has been previously considered that single-phase current was unsuitable for electric braking, but during the last few years the Oerlikon Company has developed a system which it is claimed removes this limitation. The arrangement is indicated in an elementary manner in Fig. 9. It will be seen that the armature of the motor is connected in series with a choking coil C across the adjustable voltage tapping E_1 of the transformer T. The series field windings are connected to another suitably chosen tapping E_2 on the same transformer. With these arrangements of the connections and a suitably dimensioned reactance, the machine when acting as a generator opposes to rotation an approximately constant torque from standstill up to high speeds. This can be readily illustrated in an elementary manner if, as a first approximation, we assume the machine to be without ohmic and iron losses. The vector diagram is then of the simple form shown in Fig. 9. The magnetising current I_2 and flux F produced by it are displaced 90 deg. with respect to the two voltages E_1 and E_2, which are in phase with each other. The voltage E_r induced by the rotation of the armature is in phase with I_2 and F. To complete the diagram the current I_1 in the armature circuit is displaced 90 deg. with the resultant of the voltages E_1 and E_r. Then we have—

$$F = \text{const. } I_2 = \text{const. } E_2$$

$$I_1 = \frac{\sqrt{E_1^2 + E_r^2}}{X},$$ where X is the reactance of the choking coil C.

$$\sin\varphi = \frac{E_1}{\sqrt{E_1^2 + E_r^2}}$$

The torque = const. F I_1 sin φ

$$= \text{const. } E_2 \frac{\sqrt{E_1^2 + E_r^2}}{X} \cdot \frac{E_1}{\sqrt{E_1^2 + E_r^2}}$$

$$= \text{const. } \frac{E_1 E_2}{X}$$

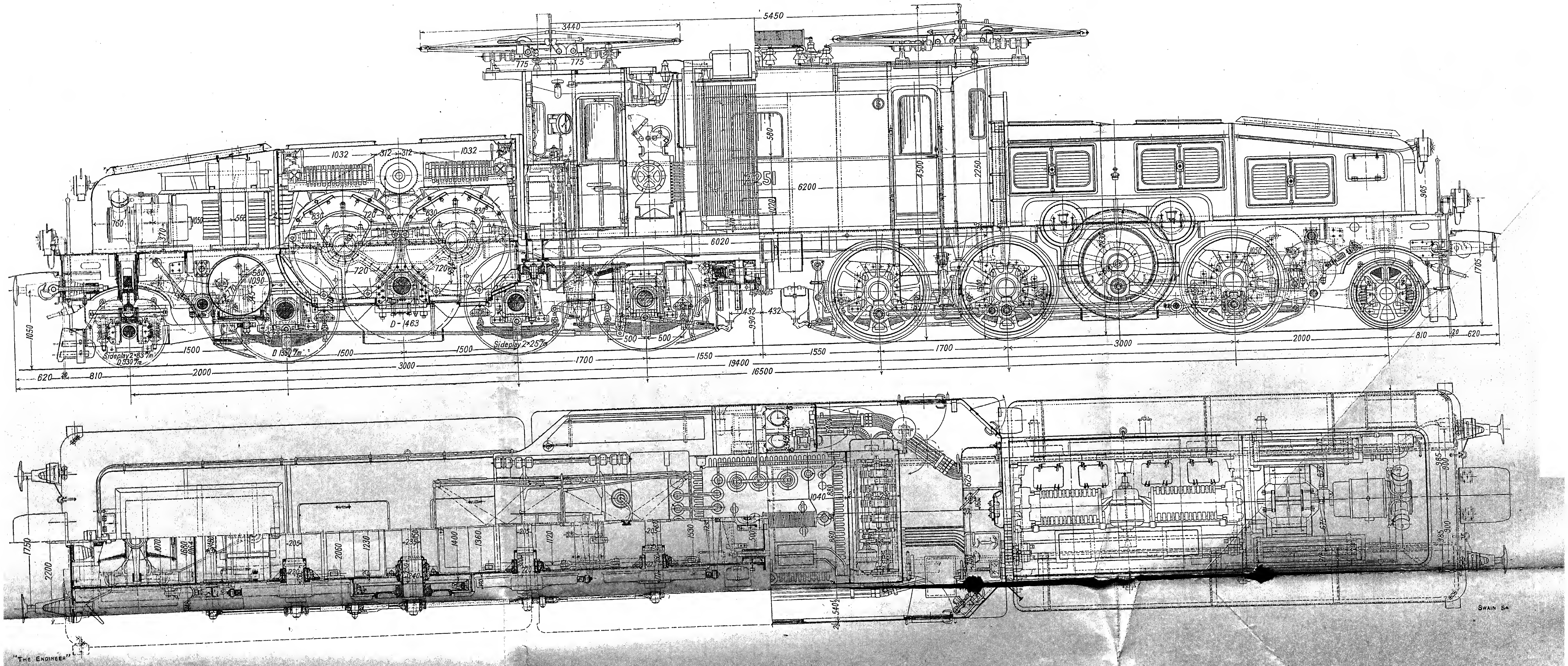
Namely, with a given excitation and terminal pressure the torque is constant and the output $E_1 I_1 \cos\varphi$ or $E_r I_1 \sin\varphi$ is proportional to the speed. The torque varies proportionally to the terminal pressure E_1, and in inverse proportion to the reactance X. The theoretical curves in Fig. 9 have been drawn for three different values of E_1 in the ratio of 1 to 0.6 to 0.3. The excitation is adjusted so that the generator gives 100 per cent. voltage at 100 per cent. speed.

As a motor, the machine does not possess series motor characteristics and operates at a lower power factor than the ordinary series motor, so that there is no special advantage in using the machine in this manner. The conversion of the machine operating for regenerative braking into the ordinary series motor for driving the locomotive is effected by short circuiting the choking coil and connecting the field windings in series with the armature. It will be seen that the additional equipment provided for regenerative braking consists of a choking coil with the addition of another small choking coil in parallel with the interpole windings of the motor for improving the commutation.

The handling of the brake is straightforward, since the braking effect is regulated by the same controller and step switch as used for motor control operation. The change over from running to braking is made by means of the reverser, which is designed to include this operation. A service application of the brake is as follows :—When running on to a down gradient the step switches are brought to the zero or off position ; the reversers are then moved to the "brake forward" position, and braking is then commenced by operating the main controller hand wheel in the driver's stand. On the first steps the braking effort is relatively small, and is gradually increased by turning the controller wheel, whereby the braking current is increased. Any desired speed can be obtained, as the control is similar to the control of the motors, the same number of steps being available for braking as for running, and braking effects can be obtained right up to "stop." The brake choking coil prevents the current in the motors becoming excessive, right up to the "stop" position. It is claimed that the braking can also be commenced at the highest speed without excessive sparking of the motors or causing any current surges. Furthermore, the braking is unaffected by pressure or periodicity variations in the overhead line. The full braking effort can be immediately cut out by means of the main oil switch in the event of the current collector breaking or leaving the overhead line without any injurious effects resulting from the mishap. When the down-gradient section is passed upon which electric braking has been used, or if the train has been brought to a standstill, the step switches are returned to the zero position by means of the controller, and the reversers operated by bringing the reversing lever to the "forward running" position, when the motor connections are again made for starting. It may be mentioned that the interlocking of the various parts of the electrical equipment, as used when running for safety purposes are also in operation when braking, so that mistakes by the driver are prevented. As already indicated, a characteristic of the braking system is that the braking effort is entirely independent of the speed, and depends only upon the pressure ; thereby inconsistencies of braking are eliminated. Any desired speed can be obtained with a given train weight by regulating the braking effort. The Oerlikon Company claims that the method allows the safest possible braking electrically, and states that the operation has been proved by repeated trials made with their new locomotives on the Lötschberg line. The efficiency of the regenerative braking under normal service conditions is given as approximately 75 per cent.; the power factor of the regenerated energy is between 0.6 to 0.7, ignoring the power used for auxiliary apparatus—compressors, fans, &c. If these are considered, the power factor is about 10 per cent. lower. Against the many advantages there appears to be one small disadvantage in the slight increase of the weight of the locomotive, due to the brake choking coil. This, however, only amounts to about 3 to 4 per cent. of the total weight of the locomotive, or 7 to 9 per cent. of the weight of the electrical equipment.

SWISS FEDERAL RAILWAYS—SINGLE-PHASE ELECTRIC GOODS LOCOMOTIVE

ATELIERS DE CONSTRUCTION OERLIKON, SWITZERLAND, ENGINEERS



Particulars of Road and Locomotive.

Track—

- Section Goldau-Chiasso .. .. 112 miles
- Maximum gradient .. .. 1 in 38
- Level difference between Goldau and main tunnel .. 2100ft.
- Level difference between Chiasso and main tunnel .. 3000ft.
- Minimum curve radius .. .. 590ft.
- Minimum curve radius on points .. .. 375ft.
- Gauge .. .. 4ft. 8½in.
- Rail weight per yard .. .. Approx. 96 lb.

Overhead line—

- System .. .. Single phase A.C.
- Pressure .. .. 15,000 or 7500 volts
- Periodicity 16⅔
- Height of wire above rail level .. .. 15ft. 9in. to 23ft.

Locomotive—

- Horse-power at wheel rims at 22½ miles per hour:
  - Continuous rating .. .. 1700 horse-power
  - 1½ hour rating .. .. 2200 horse-power
  - 15 minutes rating .. .. 2520 horse-power
- Draw-bar pull at 22 miles per hour continuous rating .. 28,800 lb.
- Draw-bar pull at 22 miles per hour 1½ hour rating .. 38,400 lb.
- Draw-bar pull, maximum 48/52,800

Locomotive (*continued*)

- Maximum speed .. .. 40 miles per hour
- Length over buffers .. .. 63ft. 8in.
- Extreme distance between wheel centres .. .. 54ft. 2in.
- Extreme distance between wheel centres on one bogie .. 22ft.
- Extreme distance between driving wheel centres on one bogie .. .. 15ft. 5in.
- Diameter of driving wheels .. .. 4ft. 5in.
- Diameter of trailing wheels .. .. 3ft. 0½in.
- Crank-pin radius .. .. 11¾in.
- Gear ratio .. .. 1 : 4.03
- Maximum height of locomotive over driver's cab .. .. 12ft. 4in.
- Maximum width of locomotive .. .. 9ft. 9in.

Locomotive (*continued*)

- Weight of mechanical part, including Westinghouse air brake .. .. 70.6 tons
- Weight of electrical equipment, including apparatus for regenerative braking .. .. 56.4 tons
- *Personnel* and accessories, &c. .. .. 1 ton
- Total weight ready for service .. .. 128.0 tons
- Axle loads .. .. 12—18.2—4 @ 16.9—18.2—12 tons
- Adhesive weight .. .. 104 tons
- Coefficient of adhesion at 1½-hour rating .. .. 1 : 6.1
- Coefficient of adhesion at starting .. .. 1 : 4.73-1 : 4.33
- Weight per yard of length .. .. 6.1 tons

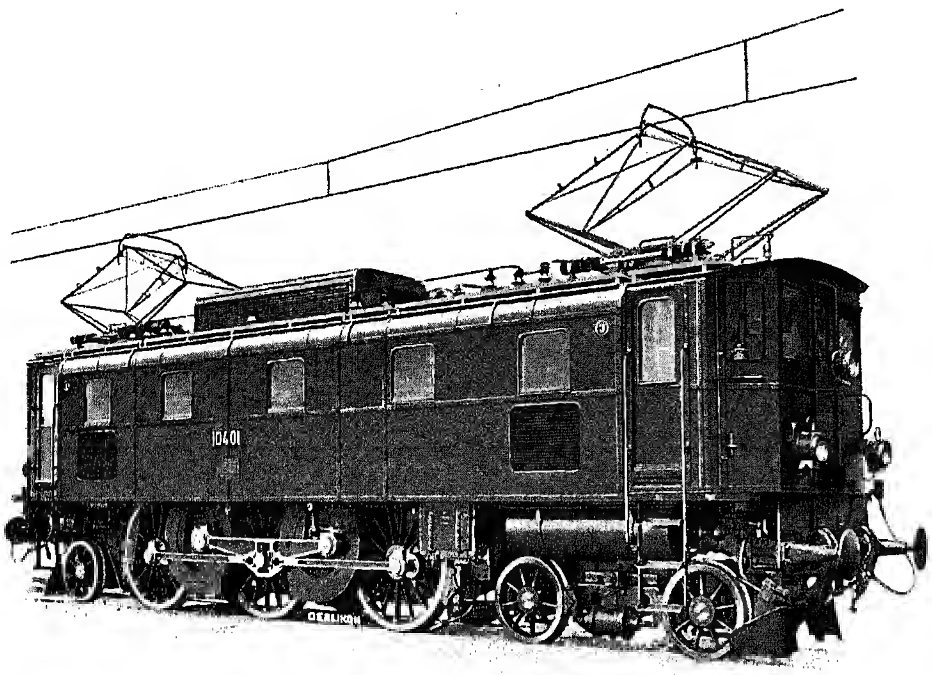


Fig. 1. Express locomotive of the Swiss Federal Railways, fitted with Oerlikon compressor, Type CAH.

SMALL OERLIKON COMPRESSORS AND VACUUM PUMPS.

A. General Remarks.

The small Oerlikon compressors are used with advantage wherever compressed air is required in quantities up to 140 cu. ft./min. and at pressures up to 115 lbs/sq. in. (gauge). They are specially suited for the following purposes:

Traction: for the remote control of signals and points, for the electro-pneumatic operation of switchgear; for actuating compressed air brakes, pantographs, sand sprays and whistles of locomotives, tramcars and motor coaches driven electrically, by petrol motors or by other such means; as portable sets, for testing the brakes of individual coaches or trains.

Mines, building sites and workshops: as stationary and portable equipments, for operating drilling machines and auxiliaries, for the supply of compressed air in galleries, for foundation work, for sand blast apparatus, for colour sprays, for operating all compressed air tools, specially for riveters, for dust blow out installations, etc.

The Oerlikon vacuum pumps create very rapidly a vacuum of 22.8 in. mercury. Owing to small power consumption and very compact design, these pumps have found a very wide field of application. They are specially suited for the following purposes:

Traction: for operating the vacuum brakes of locomotives, tramcars and motor coaches of all types; as portable sets, for testing the brakes of individual coaches or trains.

Industries: for creating the vacuum required during drying out operations in connection with the manufacture of certain electrical gear, insulation material, etc.; vacuum up to 95%.

Transformer installations: for creating the necessary vacuum during the drying out of oil.

In order to be in position to supply plant with small weight and requiring little space, capable of meeting the most varied conditions, the following types of compressors and vacuum pumps have been evolved.

Type A	with 2 cylinders disposed as a "V", in upright position.
Type AH	with 2 vertical cylinders arranged one behind the other, in upright position.
Type AI	with 1 vertical cylinder, in upright position.
Type T	with 2 horizontal cylinders arranged in opposition to each other, in inverted position.
Type TH	with 2 horizontal cylinders, arranged one behind the other, in inverted position.
Type TI	with 1 horizontal cylinder, in inverted position.
Type F	for mounting at end of motor shaft, with 1 vertical or horizontal cylinder; motor arranged in the usual way or inverted. This type is only suitable for quantities of air up to 5.3 cu. ft/min.

All these types can be used for stationary and portable equipments; the plant is self-cooled. The compressors and vacuum pumps have been designed to meet the very severe conditions laid down by railway authorities; they are characterised by the following features:

Robust construction: The Oerlikon Company has had over 20 years experience in the construction of locomotives and traction material in general, and has thus been in position to produce designs of compressors and vacuum pumps to meet the most severe traction conditions.

Small space required. The Oerlikon compressors and vacuum pumps are driven by high speed electric motors, through reduction gear, and require very little room. The type with vertical cylinders and the inverted tramcar type with horizontal cylinders, in particular, are specially built with a view to obtain the maximum output with the smallest dimensions of plant. The tables on pages 7 and 8 show the very satisfactory results obtained in this direction.

High efficiency. In view of the insertion of reduction gear between motor and compressor, it is possible to choose the most favourable speeds for both machines. The very effective lubrication provided improves the efficiency of the plant still further.

Smooth running. Crank shaft, piston rod and piston are balanced by means of counter weights, so that the compressors as well as the vacuum pumps run very smoothly, without vibration or objectionable noise.

Very little attention required. The accessories of the compressors comprise, in the case of large units, a governor which acts direct upon the switch, and, for small units, a no-load valve; consequently, no attendance is required, apart from the daily inspection of lubrication. These remarks also apply to the vacuum pumps.

Easy supervision. It is sufficient to drain off, from time to time, the oil that collects in the casing.

B. Small Compressors.

The Oerlikon compressors are of the reciprocating type and self-cooled; they are, as a rule, built for a working pressure of 115 lbs/sq. in. (gauge) and can be driven either electrically or mechanically by means of chain or belt, as desired. In the former case, reduction gear is provided between motor and compressor; this gear is of very accurate design and made of special hard steel, so that every guarantee of durability and noiseless operation is afforded. In the latter case, the compressor is supplied with free shaft end.

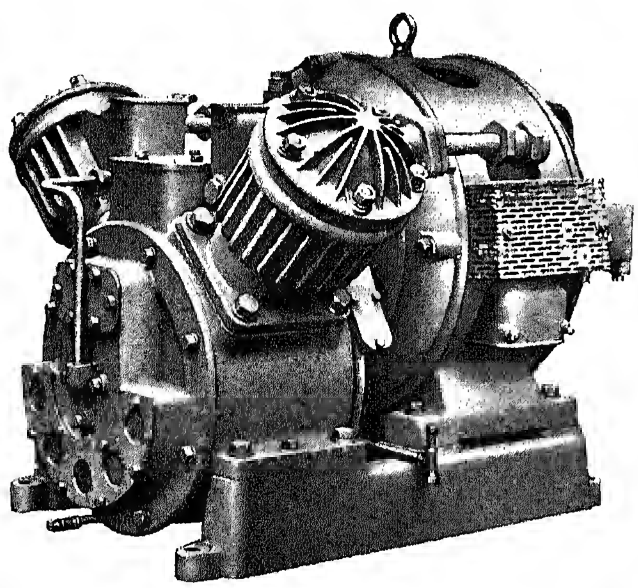


Fig. 2. Compressor, type CA, for locomotives and stationary installations.

Delivery 70 cu. ft./min., working pressure 100 lbs/sq. in. (gauge). Single-phase series commutator motor, 18 HP, 220 volts, 16⅔ cycles, 1550 r. p. m.

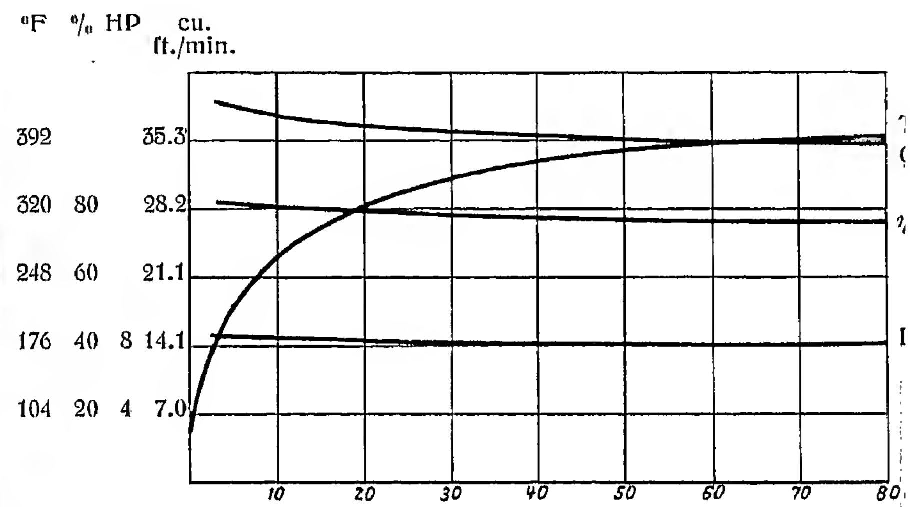


Fig. 3. Curves taken at the acceptance tests of a compressor, type CA.

Q = Delivery in cu. ft/min.
L = Output in HP.
η = Adiabatic efficiency, in %.
T = Temperature outside cylinder head, in °F.

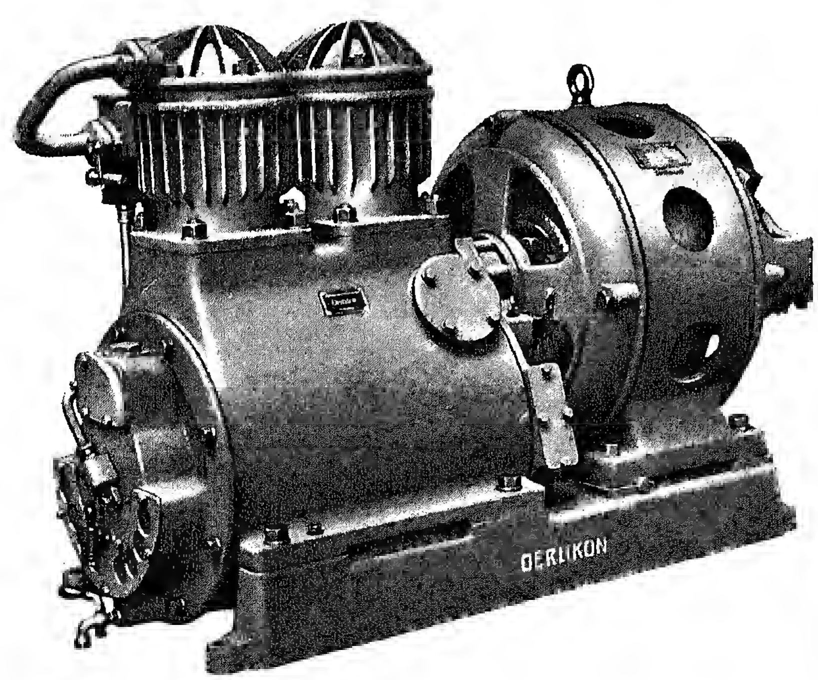


Fig. 4. Compressor, type CAH, for locomotives or stationary installations.

Delivery 70 cu. ft/min., working pressure 100 lbs/sq.in. (gauge). Single-phase series commutator motor, 18 HP, 220 volts, 16⅔ cycles, 1550 r. p. m.

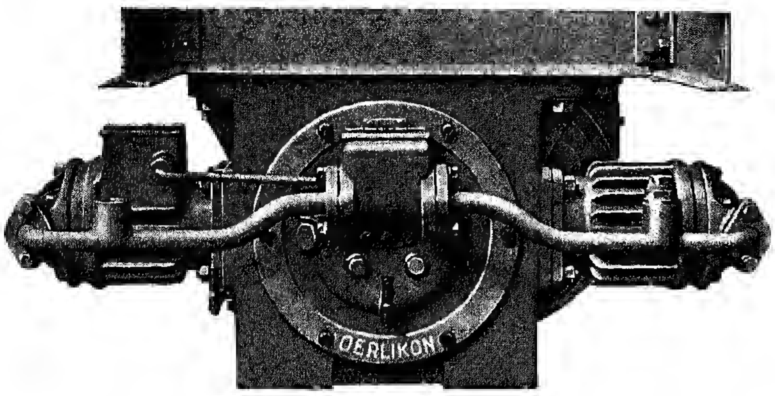


Fig. 5. Compressor, type CT, for motor coaches.

Delivery 34 cu. ft/min., working pressure 100 lbs/sq.in. Single-phase series commutator motor, 8 HP 220 volts. 16 ²/₃ cycles, 1600 r. p. m.

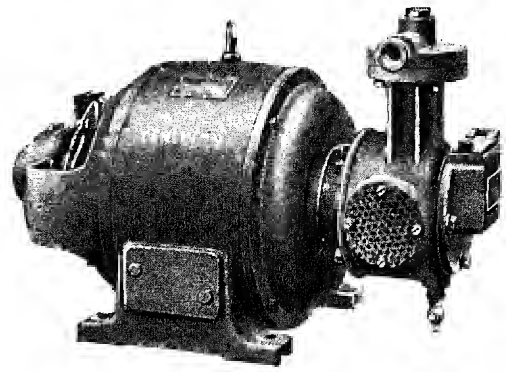


Fig. 6. Compressor, type CAF, for operating whistles and sand sprays of motor coaches and tramcars.

Delivery 1.8 cu. ft./min., working pressure 57 lbs/sq. in. (gauge). D. C. series motor 0.75 HP, 750 volts, 1000 r. p. m.

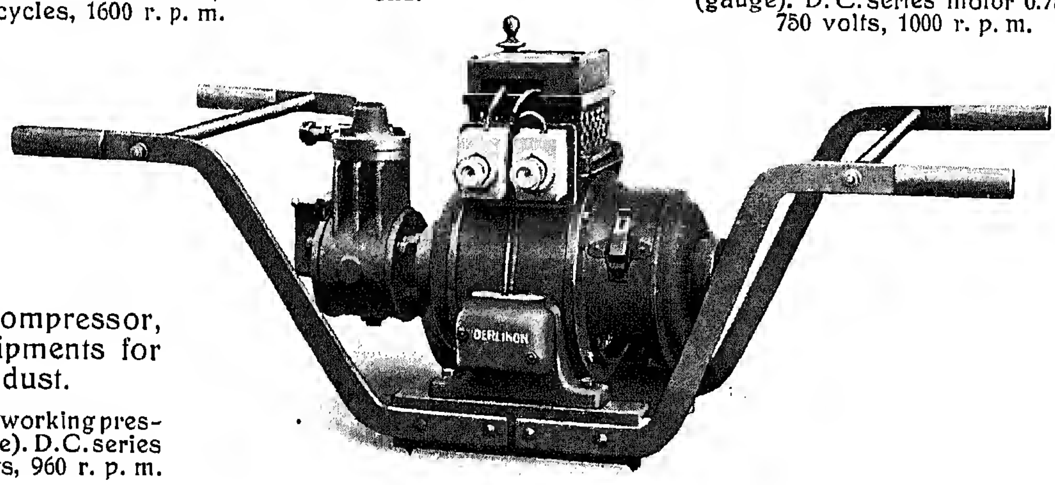


Fig. 7. Portable compressor, type CAF, for equipments for blowing out dust.

Delivery 2.1 cu. ft./min., working pressure 57 lbs/sq. in. (gauge). D.C. series motor 0.8 HP, 120 volts, 960 r. p. m.

The compressors are provided with an air filter in the suction pipe and with a safety valve. The lubrication is very copious; the oil is led to the crank bearing through the crank shaft, and from there to the piston. Oil separators can also be supplied, if desired, for preventing the oil entrained by the air from penetrating into the pipes. Lubrication and cooling are provided in such an ample way as to be sufficient for continuous operation. When not otherwise specified, the motors are rated for uninterrupted operation during 60 minutes or intermittent service with a ratio of 1 to 1 between working times and periods of rest. The motors are supplied for all current systems, pressures, and in all designs (open, enclosed etc).

In the case of automatic operation of the compressors, the following accessories can be supplied, if desired: with small units, a special no-load valve; with units of medium size, a governor which actuates a main switch, and causes the motor to operate between two given limits of air pressure in the reservoir (usually about 70 to 100 lbs/sq. in. (gauge). With large units, we supply, in addition to the device mentioned above, a centrifugal switch mounted on the shaft of the motor, which short-circuits the starting resistances under the action of the centrifugal force, when the motor has reached a sufficient speed; this device makes it possible to keep the starting current within permissible limit.

C. Oerlikon Vacuum Pumps.

The Oerlikon vacuum pumps are of the reciprocating type an dself-cooled. They are of a design similar to that of the compressors; consequently, they are suitable for the most different modes of mounting, require very little space and can be driven electrically or mechanically. The vacuum pumps serve for the production of a normal vacuum of 28.3 in., with a barometric height of 30 in. They can, therefore, reach very rapidly the vacuum of 22.8 in. required for operating the brakes. Once this vacuum is reached, it is kept constant by means of a valve.

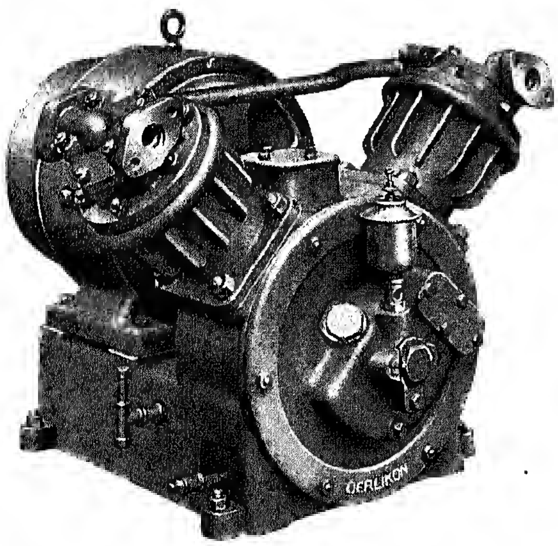


Fig. 8. Vacuum pump, type VA, for locomotives and stationary installations.
D. C. series motor, 4.5 HP, 220 volts, 2800 r. p. m.

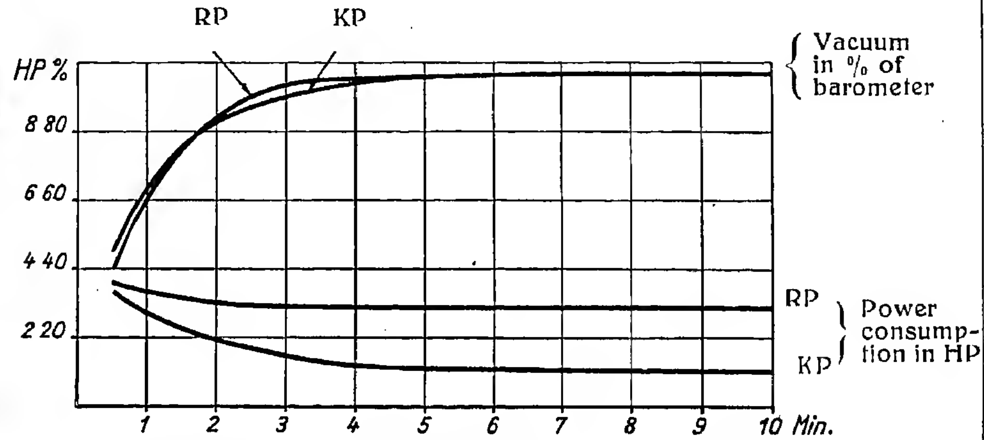


Fig. 9. Comparative results obtained with a reciprocating pump KP and a rotating pump RP, when exhausting the air in a tank with a capacity of 20 cu. ft.

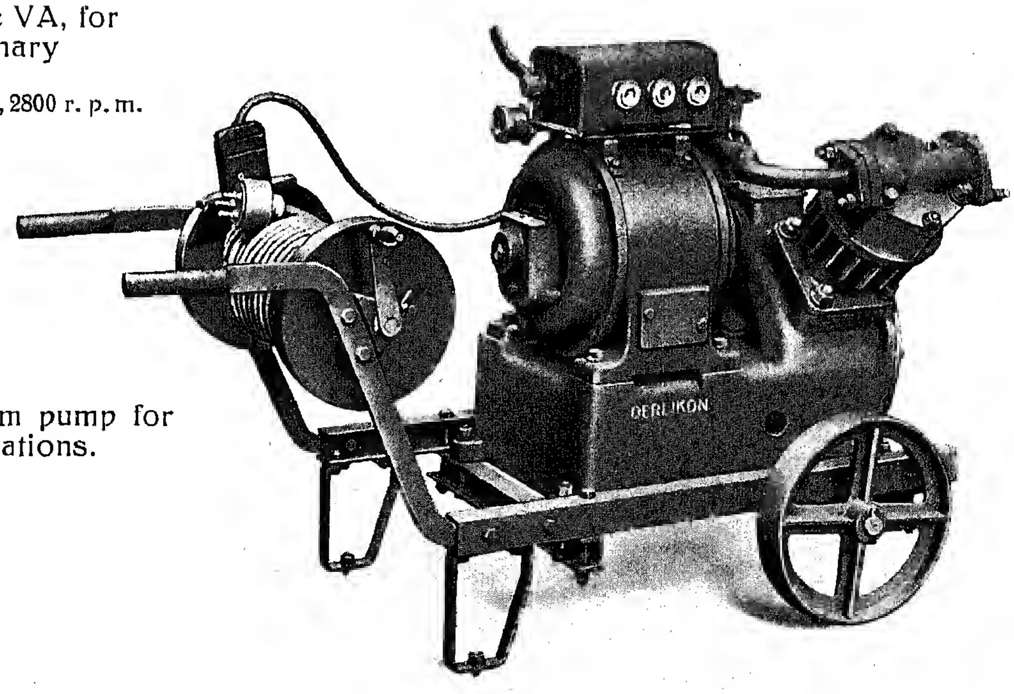


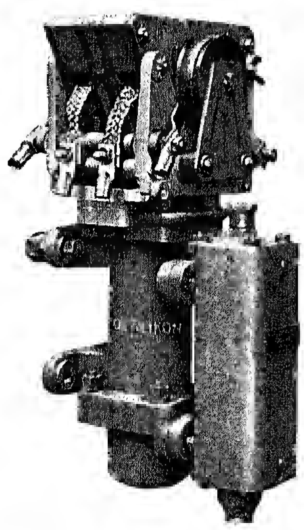
Fig. 10. Portable vacuum pump for transformer installations.

The Oerlikon vacuum pumps are built for continuous operation. In the case of large units, we recommend the provision of two speeds. The pump then runs only during short periods at the higher speed, in order to get the brakes ready as rapidly as possible, when starting; under normal conditions, however, the pump operates at half speed,

as it has only to extract the small quantity of air which penetrates unavoidably into the air pipes. The small vacuum pumps as well as the pumps with mechanical drive are only arranged for one speed. Through the provision of two speeds the power consumption is reduced to a minimum. It can, in fact, be said in a general way, that the Oerlikon vacuum pumps are characterised by their low power consumption, as can be seen from the curves in fig. 9, this being due to the small friction surfaces and to first class workmanship.

D. Accessories for Compressors and Vacuum Pumps.

The Oerlikon Company manufactures all the accessories required for complete compressors and vacuum pump equipments and the following gear, in particular:



Governors for all sizes of compressors, with main switch built on, for all supply systems, pressures and currents.
Safety valves, non-return valves.
No-load valves for small compressors.
Automatic vacuum reducing valves.
Oil separators, hand operated air pumps.

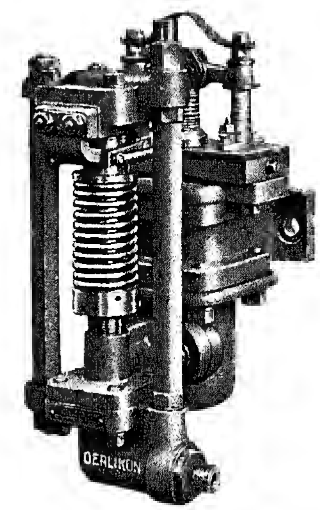


Fig. 11. Governor with switch for three-phase supply.

Fig. 12. Governor with switch for single-phase supply.

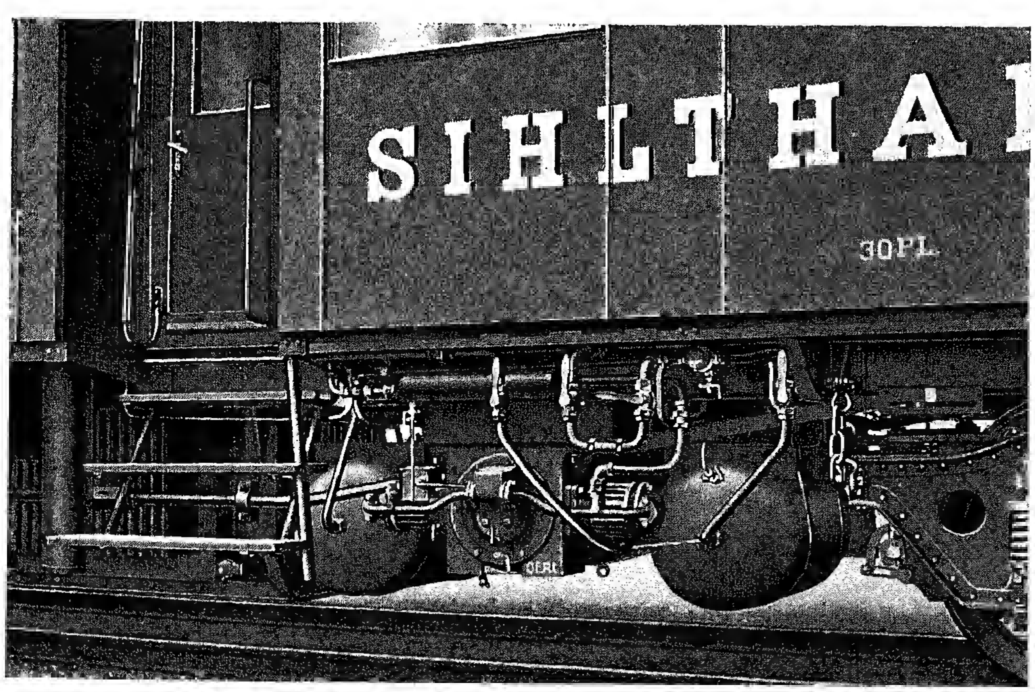
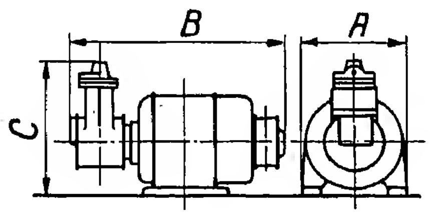


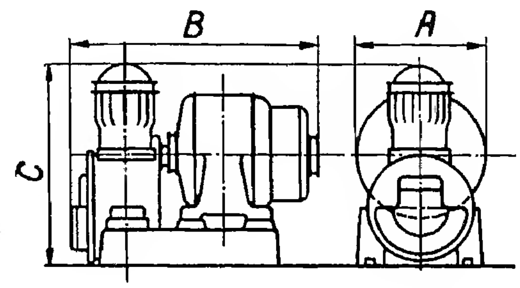
Fig. 13. View showing the mode of suspension of a compressor, type CT, on a motor coach of the Sihl Valley Railway.

Oerlikon Compressors arranged in upright position.

Main dimensions A, B, C of sets, in mm.

Type CAEF 0—1

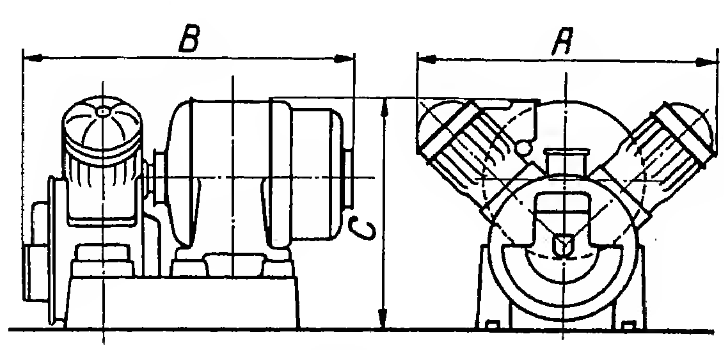




Type CAEI 2

Quantity of air delivered [1]) cu.ft./min.	Compressors Type	Power consumption at 100 lbs./sq.in.(gauge) HP	Single-phase Series-Collector-Motors [2]) 110—220 V 16 2/3 ∼			D. C. Series-Motors [2]) up to 600 V			up to 800 V			up to 1200 V			up to 1500 V			up to 1800 V			Two- and Threephase-Motors [2]) up to 500V, 50∼		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
2.8	$CAEF_0$	0.9				375	665	410													375	570	410
4.3	$CAEF_1$	1.6				470	810	510													470	670	510
9.0	$CAEI_2a$	3.2				375	770	700													375	675	700
9.0	$CAEI_2b$	3.2	470	920	700				470	920	700	410	920	700									
13.0	$CAEI_2c$	4.6				470	920	700													375	675	700
14.5	CAE_2a	5.1	720	1050	575				720	920	550	720	920	550	720	1050	575						
17.5	CAE_2b	6.2				720	920	550													720	920	550
17.5	CAE_2c	6.2	720	1050	575				720	920	550	720	1050	575	720	1050	575						
22.0	CAE_2d	8.0				720	1050	575													720	920	550
32.0	CAE_4a	10.0	860	1225	725	860	1070	675	860	1070	675	860	1070	675	860	1070	675	860	1225	725	860	1070	675
40.0	CAE_4b	13.0	860	1225	725	860	1070	675	860	1225	725	860	1225	725	860	1225	725	860	1225	725	860	1070	675
53.0	CAE_4c	19.0	860	1400	775	860	1225	725	860	1225	725	860	1225	725	860	1225	725	860	1400	775	860	1225	725

[1]) referred to the initial suction conditions for 100 lbs./sq.in. (gauge), after 15 minutes continuous operation.

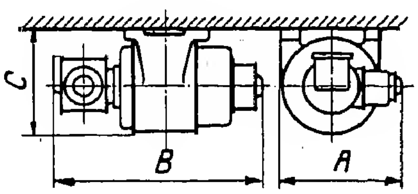


Type CAE 2—4

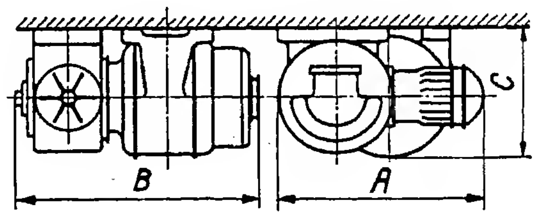
[2]) Motors for continuous operation during 60 minutes or for intermittent service, with a ratio of 1 to 1 between working times and periods of rest. Design: totally enclosed for one hour rated machines; open or enclosed ventilated for continuously rated plant.

Oerlikon Compressors arranged in inverted position.

Main dimensions A, B, C of sets, in mm.



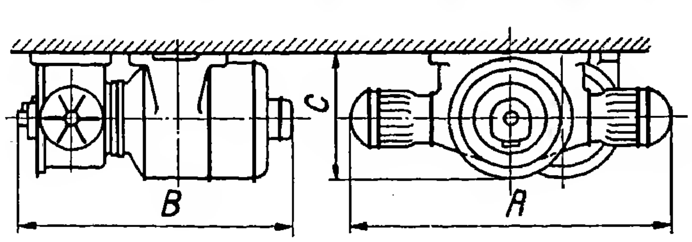
Type CTEF $_{0-1}$



Type CTEI $_2$

Quantity of air delivered [1]) cu. ft./min.	Compressors Type	Power consumption at 100 lbs./sq.in.(gauge) HP	Single-phase Series-Collector-Motors [2]) 110—220 V 16 2/3 ∼			D. C. Series-Motors [2]) up to 600 V			up to 800 V			up to 1200 V			up to 1500 V			up to 1800 V			Two- and Threephase-Motors [2]) up to 500 V, 50∼		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
2.8	CTEF$_0$	0.9				410	665	320													410	570	320
4.5	CTEF$_1$	1.6				510	810	400													510	670	400
9.0	CTEI$_2$a	3.2				700	770	370													700	675	370
9.0	CTEI$_2$b	3.2	700	920	400				700	920	400	700	920	400									
13.0	CTEI$_2$c	4.6				700	920	400													700	675	370
14.5	CTE$_2$a	5.1	1000	1050	480				1000	920	400	1000	920	400	1000	1050	480						
17.5	CTE$_2$b	6.2				1000	920	400													1000	920	400
17.5	CTE$_2$c	6.2	1000	1050	480				1000	920	400	1000	1050	480	1000	1050	480						
22.0	CTE$_2$d	8.0				1000	1050	480													1000	920	400
23.0	CTE$_3$a	8.0	1160	1260	580				1160	1100	480	1160	1100	480	1160	1100	480	1160	1260	580			
27.0	CTE$_3$b	9.3	1160	1260	580	1160	1100	480	1160	1100	480	1160	1100	480	1160	1100	480	1160	1260	580	1160	1100	480

[1]) referred to the initial suction conditions for 100 lbs./sq.in. (gauge), after 15 minutes continuous operation.



Type CTE $_{2-3}$.

[2]) Motors for continuous operation during 60 minutes or for intermittent service, with a ratio of 1 to 1 between working times and periods of rest. Design: totally enclosed for one hour rated machines; open or enclosed ventilated for continuously rated plant.

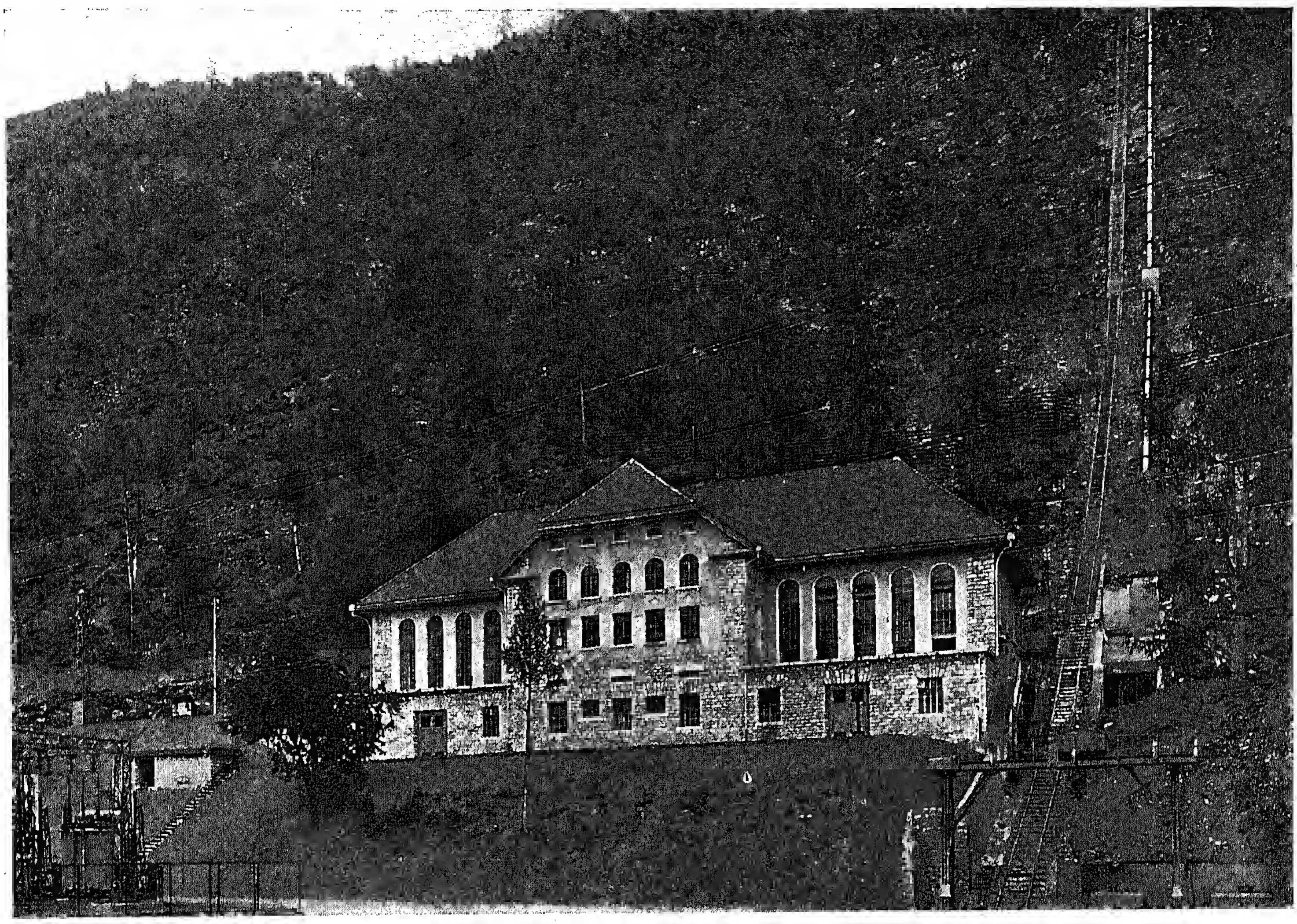
BULLETIN OERLIKON

No. 63/64 — September/October 1926

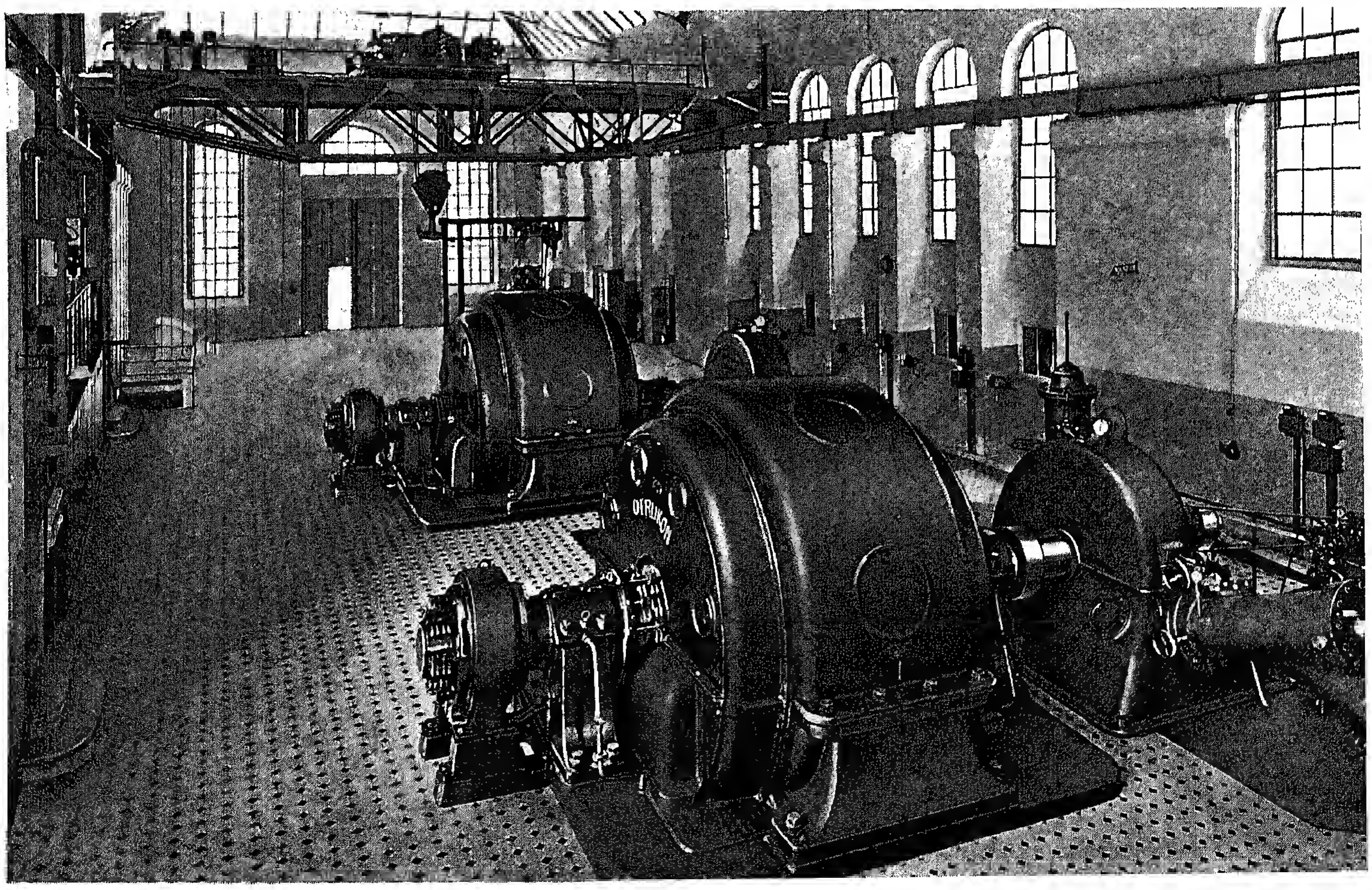
Contents: The generating stations of the Lake of Ill and Tourtemagne Power Supply Company.
Notes and News Items. Railway substation for 1600 volts. — The Felsberg automatic substation. Regenerative braking tests in connection with tramway operation. — Motor equipments of the new freight locomotives type Ce⁶/₈ of the Swiss Federal Railways. — Lifting plant for handling bulk materials and packages.

Travelling gantry crane for the handling of tree trunks.

Working load 6 tons. Span of bridge 182 ft. Overall length of bridge 213 ft.
The trunks are gripped at two places by means of special tongs, so as to increase the degree of safety when handling them.



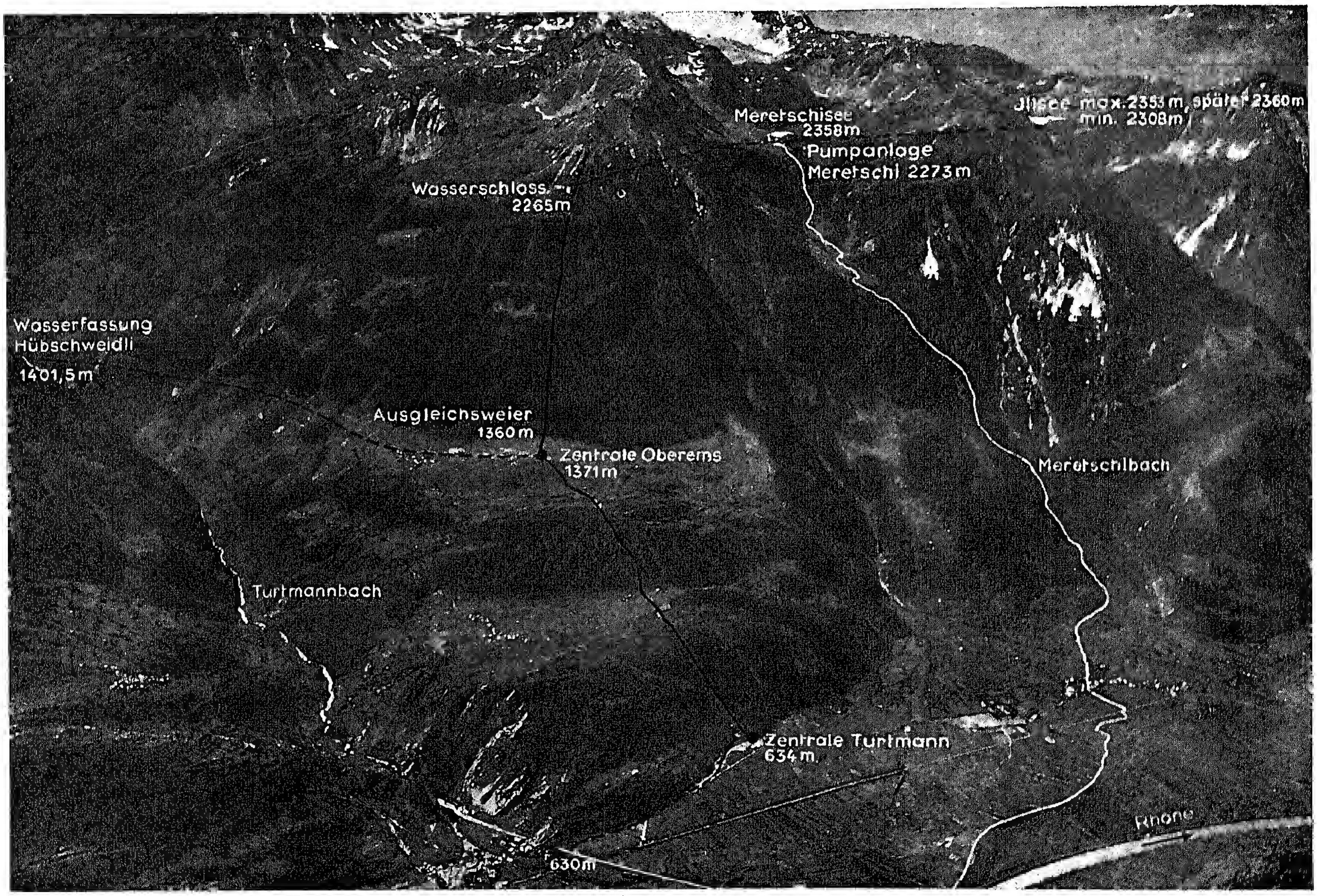
View of the Tourtemagne power station.



Machine room of the Tourtemagne power station with the two 8000 KVA three-phase generators.

The Generating Stations of the Lake of Ill and Tourtemagne Power Supply Company.

The hydro-electric power stations of the Lake of Ill and Tourtemagne Power Supply Co. are situated in the Upper Valais, opposite Louèche, on the steep mountain slopes overhanging the Rhône; they afford a typical example of a power development where a constant output is ensured throughout the year, through the combined operation of a lower generating station, for service mainly during the summer months, when the water from alpine streams is plentiful, and an upper power station deriving its water supply from a storage lake, which can make good, in winter in particular, the deficiency in power of the other generating station. The lower installation, the Tourtemagne power station, is situated down in the Rhône Valley, near Muehlackern; it utilises the water from the Tourtemagne stream, which is led through a pressure pipe line to the turbines, the head available being 2381 ft. The plant, at present provided, has a capacity of 20,000 HP. The upper installation — the Oberems power station — makes use of the water accumulated during the summer months in the lake of Ill (7708 ft. above sea level), which has been dammed in order to increase its capacity. The water is conveyed from the lake to the surge chamber in a pipe line about $2^1/_2$ miles long, laid in a tunnel, and from there through a pressure pipe line to the power station at Oberems (4496 ft. above sea level), the head available being here 2933 ft. In order to increase the quantity of water stored in the lake of Ill, a pumping station has been erected at Meretschi, near the pipe line of the Oberems power station; this installation serves to pump the water available at that point, into the lake through the pipe line, during the summer months. The whole electrical equipment for the two power stations, as well as for the



Aeroplane view showing the Lake of Ill and Tourtemagne power development, taken from a north-easterly direction.

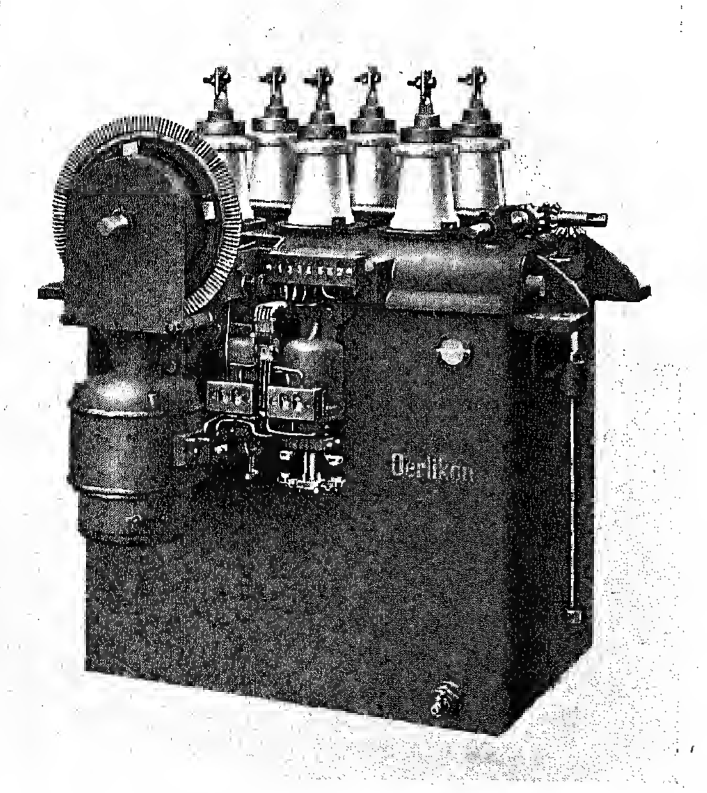
Illsee max.	2353 m	=	Lake of Ill max.	7717 ft.
später	2360 m	=	later on	7740 ft.
min.	2308 m	=	min.	7570 ft.
Meretschisee	2358 m	=	Lake of Meretschi	7734 ft.
Pumpanlage Meretschi	2273 m	=	Meretschi pumping station	7455 ft.
Wasserschloss	2265 m	=	Surge chamber	7429 ft.
Wasserfassung Hübschweidli	1401,5 m	=	Intake at Huebschweidli	4596 ft.

Ausgleichsweiher	1360 m	=	Balancing reservoir	4460 ft.
Zentrale Oberems	1371 m	=	Oberems power station	4496 ft.
Turtmannbach		=	Tourtemagne stream	
Meretschibach		=	Meretschi stream	
Zentrale Turtmann	634 m	=	Tourtemagne power station	2079 ft.
	630 m	=		2066 ft.
Rhone		=	River Rhône	

Meretschi pumping station, was supplied by the Oerlikon Company.

The Tourtemagne power station, which was put into service in the summer of last year, is at present equipped with two sets; provision has, however, been made for a third unit, to be installed at a later date. The generators are of the totally enclosed self-cooled type, the fresh air and warm air ducts being arranged under the floor of the machine room. When the outside temperature is low, the air ducts can be closed externally and the air inlet bends on either side of the machine removed, in order to permit of the air being drawn from the machine room; the warm air then escapes back into the machine room through openings provided for the purpose.

The generators are provided with overhung exciter and coupled direct to Pelton turbines; they are each designed for a continuous rating of 8000 KVA at 750 r. p. m. and are wound for 9500/10,000 volts, 50 cycles. The pressure regulation is obtained by varying the excitation of the exciter alone. The rotors were subjected to a runaway speed of 1350 r. p. m., for a minute, in the pit for overspeed tests at the Oerlikon Works, without any permanent deformation being observed. In view of the high speed of plant, the Oerlikon Company have adopted, in the case of these machines, the special rotor design evolved by them for high speed generators, where the individual poles are fastened to the rotor rim by means of claws inserted in round holes. In order to ensure great mechanical strength, all the parts of rotor subjected to stresses, and the rotor rings, in particular, are made of high grade forged steel. An important feature of these rings resides in the fact that they are machined on all sides and do not have any projecting parts, so that they can be forged without difficulty; it is thus possible to obtain a material with very homogeneous structure, and free from internal stresses. Owing to the relatively small bore of machine, a separate hub has been dispensed with, the rotor rings being shrunk direct on the shaft, which is provided with corresponding shoulders (see also Bulletin Oerlikon No. 47). When dismantling the rotor, for transport for instance, the individual poles can be removed axially, in a simple way. The stator winding is made up of former wound coils, which are insulated and impregnated by a special process, in view of the rather high pressure to be dealt with.



Oil circuit breaker for 12000 volts, with remote control equipment.

The switchgear installation is in the fore part of the power house, which is in the form of a basement reaching only up to the level of the machine room floor; this arrangement, which is specially suited for a building situated on a steep slope, as in the present case, affords a happy solution of the problem in question, not only from a technical standpoint, but also from an architectural point of view, as it gives to the whole power house, a very pleasing appearance.

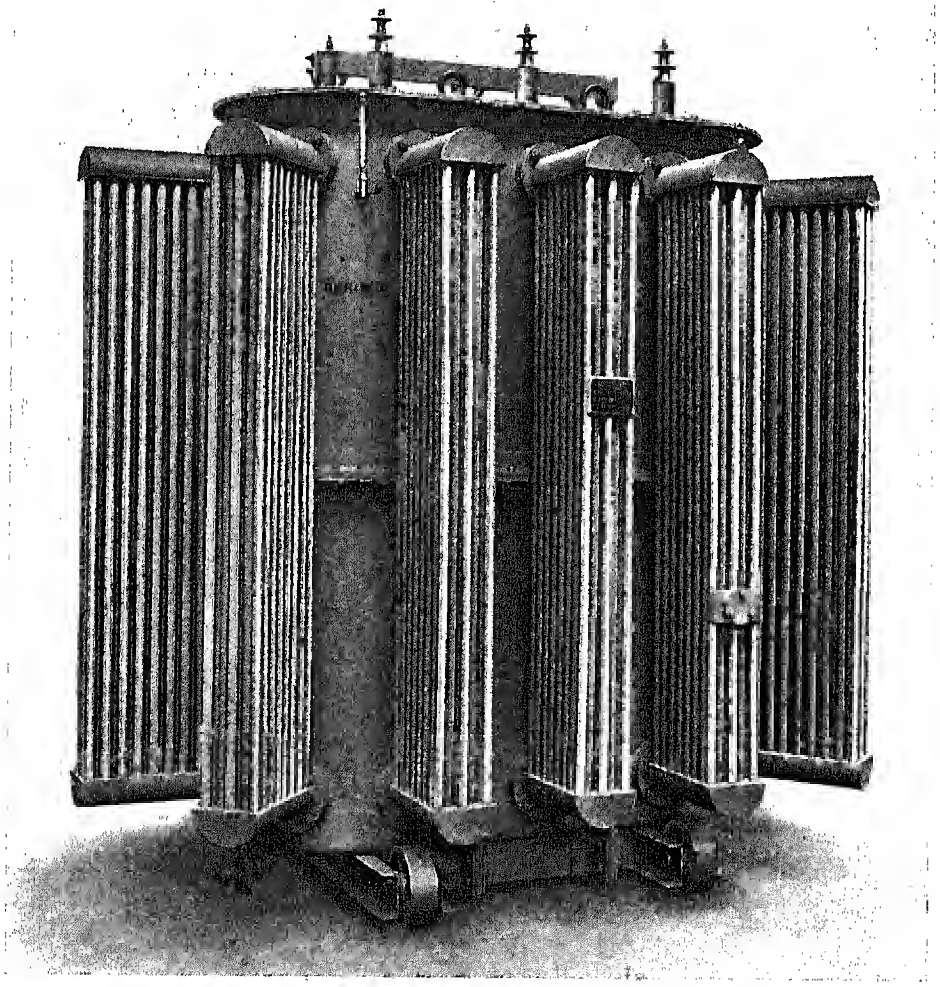
The switchgear basement is provided with two doors leading outside, while it also communicates direct with the machine room; it is subdivided into two switch rooms, one for the main services (generators and main outgoing feeders) and the other for the auxiliary services (power station supply, lighting of village, etc.), with the control room in between; the latter is equipped with two switch desks with all the necessary instruments and supervisory gear for the control of the power station. The arrangement of switchgear is such as to permit of the easy supervision of installation, while the isolating distances for the 10,000 volt gear are very ample. The whole H. T. apparatus is disposed in cubicles. Apart from this switchgear installation, which contains all the apparatus required for the generators, for the incoming cables from the upper power station at Oberems and for the outgoing circuits, there is an outdoor substation, situated close by, where the pressure is stepped up to 60,000 volts for the power transmission to Chippis. Provision has been made for two busbar systems, so that each unit can be operated independently on different services. The various 10,000 volt overhead lines for the supply of the neighbouring villages scattered over the mountain side are connected to the busbars through the intermediary of a protective transformer with a pressure ratio of 1:1. As regards protection against surges, the method adopted for this extensive overhead system, consists merely in inserting a length of cable between the overhead lines and the switch room, and providing an ordinary choking coil at the point of leading in, an arrangement which has proved entirely satisfactory for the conditions in question.

On the 10,000 volt side, use is made of single-tank oil circuit breakers; the latter have a rupturing capacity of about 100,000 KVA and are fitted with the new Oerlikon remote control equipment. With this design of remote control, the operating gear is mounted directly on the cover of circuit breaker or on the spindle, the main object aimed at being to avoid all intermediate members between the lever of the circuit breaker and the operating gear, so as to eliminate the possibility of any alteration in position of contacts through deformation, etc. It is thus possible to adjust the contacts with great accuracy and to test the circuit breaker very carefully, together with its operating gear, at the Works before despatch, this being a matter of no little importance in the case of oil circuit breakers with small dimensions, where the distance of travel of contacts is itself small and must, as far as possible, not be reduced.

A special advantage secured through the adoption of a motor equipment instead of operating magnets, for the remote control of the circuit breakers, resides in the fact that the power consumption of the former is lower (1 to 3 KVA) while, on the other hand, the motor can be chosen for use either with direct or alternating current. The operation of circuit breaker is controlled, in the usual way, by means of a master switch, without the intermediary of contactors. The torque of the motor is transmitted to the spindle of circuit breaker by means of reduction gear, which is itself provided with a friction coupling, so as to prevent jerks such as might otherwise occur owing to the effect of the liberated kinetic energy of the masses displaced. — In view of the high value of the switching in speed, which amounts to about 3 ft. per second, the gear ratio between motor and spindle of circuit breaker can be taken quite small so that the switching in time does not exceed .2 to .3 seconds, this being entirely satisfactory for paralleling operations. The circuit breakers are arranged for automatic release and fitted, for this purpose, with free handle device, the opening of circuit breaker being ensured by a spring which is compressed during the switching in operation. Provision has been made, in particular, for the release of circuit breaker in the event of the current supply of motor failing during the switching in process. On the other hand, should there be a short-circuit in the line when switching in, the circuit breaker opens immediately and remains in the "off" position, until the master switch controlling the circuit breaker is operated again; consequently, all possibility of "hunting" between the "on" and "off" position is eliminated.

The motor of operating gear is a vertical single-phase repulsion motor, deriving its current from the 220 volt three-phase supply. In view of this, it has been possible to dispense with a separate D. C. supply for the operation of the numerous oil circuit breakers, a small battery of accumulators being sufficient for the requirements of the trip coils. The oil circuit breakers are released indirectly by means of relays used in conjunction with instrument transformers; the relays are of the induction type and fitted with time lags. In order to prevent the generator pressure from reaching an excessive value, provision has been made for maximum pressure relays which come into play at a pressure about 20 % above normal. The effect of these relays is to cause first a momentary throttling of excitation, after which the release of circuit breaker takes place.

The Oberems power station is equipped, for the time being, with two generating sets, accommodation being further provided for a third unit. The generators are of the same type as those at the Tourtemagne power station, but are built for coupling to 5600 HP turbines; the continuous rating of these machines is 4200 KVA at 9800/10200 volts, 750 r.p.m. As regards design, the particulars given for the generators at the Tourtemagne power station apply also to the present machines. The power is transmitted from the Oberems power station to the Tourtemagne power station at generator pressure by means of two cables run alongside the pressure pipe line. As the route followed includes gradients up to 1 in .91, it was necessary to take special precautions when laying the cables. The switchgear installation is here at the same level as the machine house and built on to it, while the control room, with the two switch desks, is disposed higher. The apparatus is arranged, in the present case too, in such a way as to permit of the easy supervision of installation. The whole switchgear equipment is of the same design as that at the Tourtemagne power station; in view of this, the individual parts can be rapidly changed, while the number of spares required is considerably reduced.



One of the 1500 KVA transformers of the Meretschi pumping station.

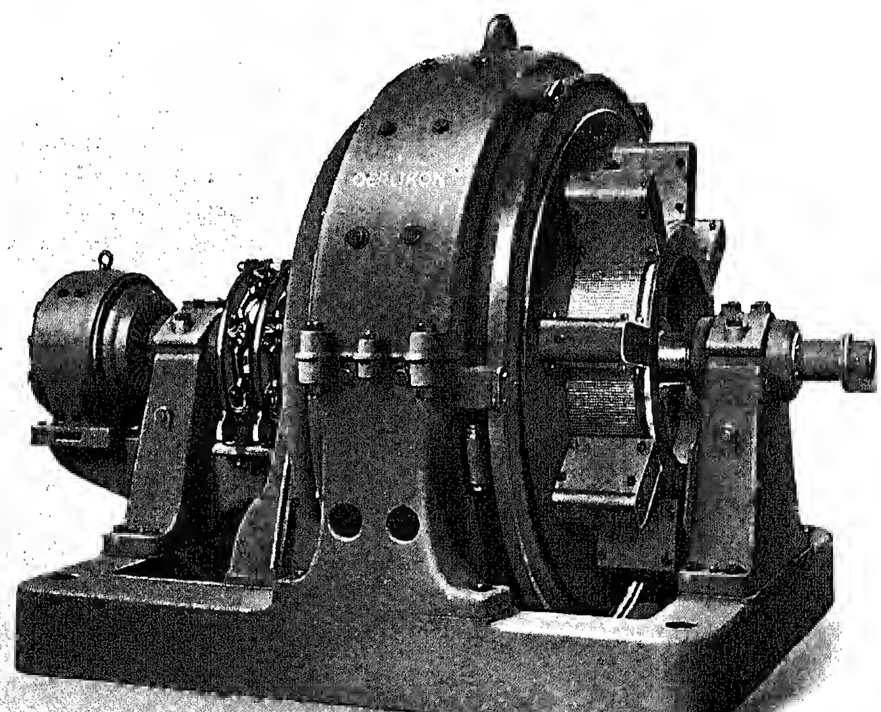
The Meretschi pumping station which is situated at an altitude of 7455 ft., in the neighbourhood of the pipe line from the lake of Ill to the Oberems power station, is equipped, for the present, with three pumping sets; provision has, however, been made for six units in all. The sets each consist of a three-phase induction motor of the enclosed ventilated type with an output of 500 HP at 1470 r. p. m., 500 volts, direct coupled to a two-stage high pressure centrifugal pump. The speed can be regulated down to about 900 r. p. m. by means of slip regulation, and the machines run continuously at that speed.

This large range of regulation was necessary owing to the very different conditions as regards head and delivery under which the plant has to operate, the head being liable

to vary between about 130 and 360 ft., according to the level of the lake of Ill. The starting up of motor and regulation of speed is ensured by means of combined starting and regulating gear. For starting up and fine regulation, use is made of water resistances, while cast iron grid resistances are utilised for coarse regulation; the latter serve also for heating purposes in winter, as, at those high altitudes, very low outside temperatures have to be reckoned with.

The pumping station equipment includes all the instruments and cables such as are required for permitting of the easy adjustment of the speed and delivery of pump, for every value of head. The power for driving the pumping sets is obtained from the Oberems power station, from where it is transmitted, by means of a cable laid in the tunnel of the pipe line, to a substation close to the pumping station, where the pressure is stepped down from 10,000 volts to 500 volts, to suit the motor. The transformer plant comprises two self-cooled oil immersed three-phase transformers, with tank in two parts, and built-on stacks of cooling tubes. This design had to be adopted in view of the fact that all machine parts for the pumping station had to be conveyed from the Oberems power station first by a cable railway running alongside the pipe line, up to the surge chamber, and from there to Meretschi through the tunnel of the pipe line, where the small dimensions of passage imposed very severe limitations on the size of parts to be transported.

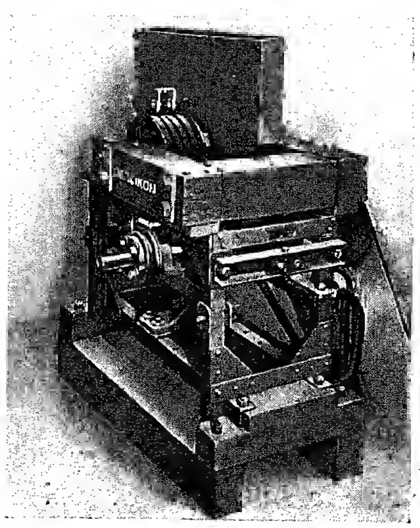
The substation further includes, apart from the main transformers, two station transformers for lighting purposes, as well as the necessary switchgear, all plant and apparatus being arranged in cubicles. The switchboard, with all the instruments, master switches, etc., is, however, in the pumping station, so that the whole installation can be controlled from one point. — The circuit breakers both for the primary and secondary side of the 1500 KVA transformers are, as in the case of the two power stations, fitted with A. C. remote control, and arranged for automatic release by means of relays of the induction type. As there is no D. C. supply available for the release of circuit breakers, special A. C. trip coils have been provided; the latter are so designed as to ensure their operation even when the pressure drops very low, as is usually the case when a short-circuit occurs, a pressure down to about 8 % normal pressure being entirely sufficient to bring them into play. The arrangement occasionally resorted to, where a no-volt trip coil, connected in series with a resistance, is short-circuited by the relay, cannot be regarded, in a general way, as satisfactory, as the tripping device comes into play instantaneously, of itself, when the pressure drops below about 60 % normal pressure; consequently, the time adjustment of the overload relay becomes then entirely useless.



The A. C. trip coils evolved by the Oerlikon Company offer, on the other hand, every guarantee of reliable operation, under all working conditions; they are specially suitable for use in distribution stations and substations where large outputs have to be interrupted and no D. C. supply is available. The installations in question, which are very substantially built, and designed with a view to avoiding all unnecessary complications, have given the best results in service.

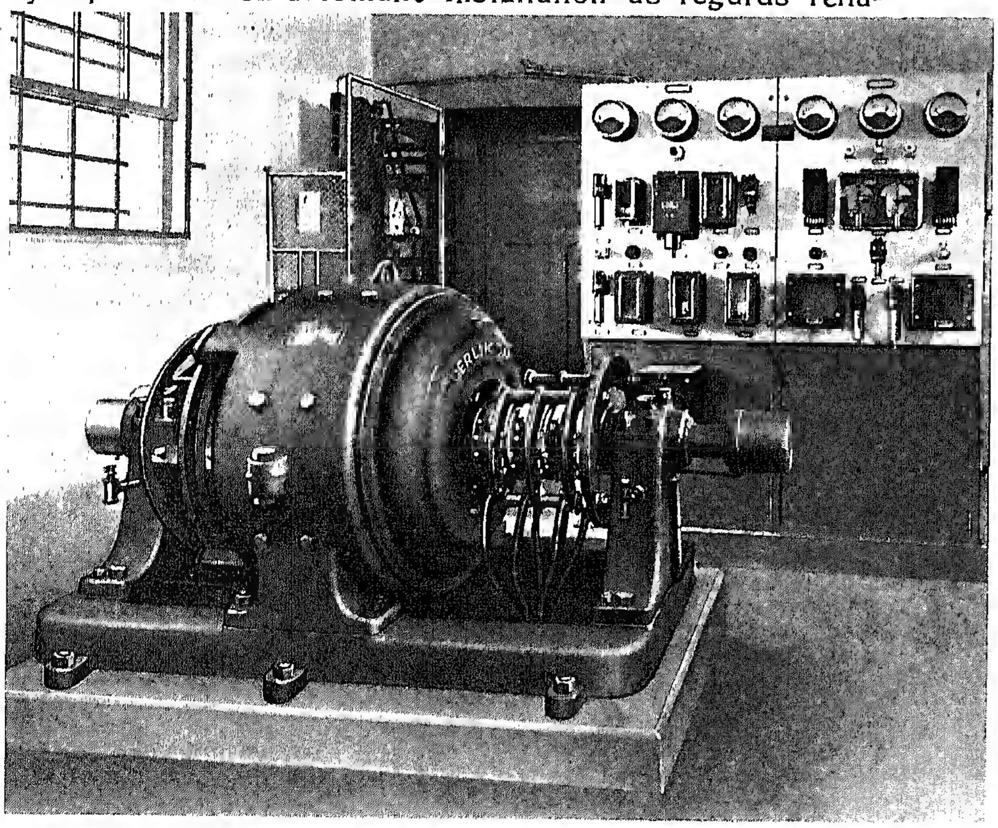
Notes and News Items.

Railway substation for 1600 volts. The Oerlikon Company supplied at the beginning of July of this year a rotary converter for 1500/1600 volts D. C. with complete substation equipment, for the Wengernalp Railway. The machine in question which is illustrated above has a continuous output of 750 KW and is installed in the railway sheds at Grund near Grindelwald; it is designed for operation at 40 as well as 50 cycles and works in parallel with the existing power station situated about 9 miles away, near Wengen, on the other side of the Kleine Scheidegg, the latter being equipped with three generators and a battery of accumulators. The switchgear of the new substation includes, in particular, one of the new Oerlikon quick-acting circuit breakers for remote control. This circuit breaker which is also illustrated here has a continuous rating of 1000 amps; breakers of this type have already been used in many other installations with the best results. The substation was taken over in the middle of July, immediately after erection and has since then been in regular service. Further particulars of this interesting plant will be given in a subsequent issue.



The Felsberg automatic substation. This substation was built by the Oerlikon Company for the Saarlouis Power and Traction Company and put into service last May. The substation in question is situated at Felsberg on the Saarlouis-Kreuzwald railway line, its object being to assist the main power station at Saarlouis when, owing to a heavy load, the supply pressure drops below the limits permissible for the operation of the line. The equipment consists of one 150 KW rotary converter for 800 volts on the D. C. side, with the necessary transformer and apparatus. The installation is arranged throughout for automatic operation. The rotary converter is started up automatically and switched on to the system when the pressure drops below 700 volts, for more than 15 seconds, while it stops also of itself when, for a period of five minutes, the current supplied does not exceed 25 amps.

Both the rotary converter and the other parts of the installation are built in such a way as to render them entirely proof against the effects of short-circuits, and the relay contacts are designed with great care, while the mode of connection has been simplified to the utmost degree. In this way, it has been possible, to construct a substation which not only equals a non-automatic installation as regards reliability in operation, but is even superior to it. Since the opening of the substation, the plant has been switched on and off some 2 to 300 times and subjected to numerous short-circuits, without this causing any disturbances.



Felsberg automatic substation.

Regenerative braking tests in connection with tramway operation. The tramway system of the City of Zurich includes a number of lines with long and steep gradients. In view of this, it was thought that there would be scope for effecting saving in power on such sections by resorting to regenerative braking during downgrade operation. In order to collect data in this connection, a series of tests were carried out, the necessary equipments being supplied by the Oerlikon Company, at the request of the tramway authorities. We are giving below a few particulars regarding the arrangement adopted for the test, together with the results obtained during one of the trial runs. — With the method of regenerative braking adopted, the series motors of traction equipment are converted into shunt machines by altering the connection by means of a special controller. The field windings of motors are connected in series, through a suitable resistance, to the supply, while the armatures, in the case of two-motor equipments, are also arranged in series and linked up to the system through a variable starting resistance and a constant damping resistance. The starting resistance is reduced on the first notches 1—4 of the controller, while the field resistance is increased on notches 5—7. Apart from these notches provision is made for the usual braking positions. The equipment in question was fitted on a service car built for other tests and designed to the following particulars:

Weight of empty car	10.05 tons.
Adhesive weight	8.0 tons.

4 driving wheels 860 mm. in diam., 4 running wheels. — 2 motors with double reduction gear 1:9. — Spur and bevel gears*).

Rating per motor	continuous	one-hour
Current	69	94 amps.
Output at wheel	35.5	48.5 KW
Tractive effort at wheel	1020	1560 lbs.
Speed	17.4	15.5 m.p.h.

The readings 1—7 in the table below were taken on level track. They represent the condition of equilibrium reached on each notch. Measurements were then made on steep gradients, first with the service car alone, then with a second tramcar used as trailer, and finally with the second tramcar having its motor switched on, in order to increase the necessary braking force. Readings 13—41 are some typical results obtained during these tests. The figures arrived at coincided very accurately with the calculated values. The current regenerated was, as had been foreseen, not considerable. In fact it would only be possible to obtain good results with regenerative braking in the case of four-motor equipments, as the field current would then be small as compared with the armature current (2 armatures in parallel). It was, however, seen from the tests that with the two-motor equipments the arrangement adopted worked perfectly well and was easy to control both when running and braking.

The tests further demonstrated that the regeneration of current with the method of connection in question was quite practicable from a technical point of view and only required little more attention from the staff than the ordinary running arrangement.

*) For further particulars regarding drive, see Revue Polytechnique Suisse No. 24 of 12th. June 1926.

Reading No.	Weight of train tons	Gradient	Notches No.	Speed m.p.h.	Supply pressure volts	Current in field amps.	Current in armature amps.	Current from overhead line amps.	Controller notches on trailer
1	10.7	level	1	—	525	110	10	120	
2	10.7	„	2	3.1	550	116	9	125	
3	10.7	„	3	3.7	545	114	12	126	
4	10.7	„	4	4.3	535	111	14	125	
5	10.7	„	5	4.9	560	94	14	108	
6	10.7	„	6	—	525	72	14	86	
7	10.7	„	7	6.2/7.4	545	62	15	77	
13	10.7	1 in 1.5	6	7.4	565	80	—38**)	42	
14	10.7	1 in 1.5	7	8.6	570	68	—38	30	
30	22.2	1 in 1.49	7	12.7	595	62	—78	—16**)	
34	22.2	1 in 1.5	7	13.9	600	68	—105	—37	6 (series)
35	22.2	1 in 1.5	6	11.8	590	76	—92	—16	6 „
41	22.2	1 in 1.5	1	7.7	565	154	—88	66	6 „

**) The sign — in the table means regenerated current.

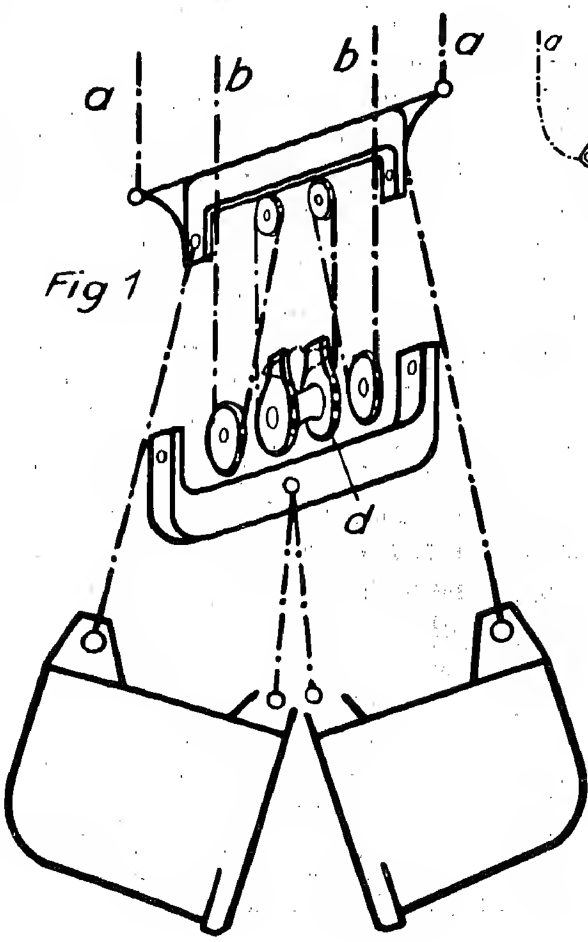
Motor equipments of the new freight locomotives type Ce $^6/_8$ of the Swiss Federal Railways. The Oerlikon Company is at present building for the Swiss Federal Railways, 18 heavy freight locomotives, which differ from those formerly supplied in that they are for a larger output. In order to determine the heating of the motor equipments and ascertain their performance as regards output, one of the motors of these new locomotives was provided with thermo-couples and recently subjected to a series of load tests, the thermo-couples being arranged as near as possible to the conductors of the stator and rotor windings. The results of these tests are given in the following table, together with the data on which the calculations of motors were based, for the sake of comparison.

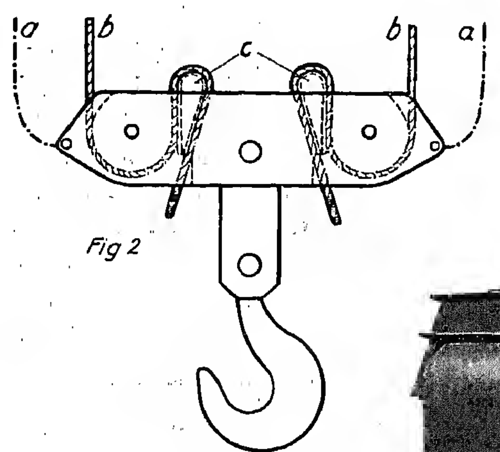
	Continuous rating amps.	KW	r.p.m.	One-hour rating amps.	KW	r.p.m.
Data for calculation of motor	1400	435	620	1600	485	555
Performance at tests:						
a) with temperature rise according to the regulations of the Swiss Federal Railways (AIEE 1915 for stationary machines)	1550	480	560	1730	530	530
b) with temperature rise according to the American Rules (AIEE No. 11, 1925)	1780	545	520	2070	610	480

The pressure for all the tests was 360 volts. The tests have shown how very amply the motor equipments are designed. In fact, the motors in question would even be large enough for the express locomotive recently standardised by the Swiss Federal Railways, as the temperature rise would then be still just within the permissible limits.

The speeds of the freight locomotives for the one-hour and continuous rating (41 and 40.5 m.p.h., respectively) actually correspond to those provided for in the case of the express locomotives. The highest normal motor speed of 1030 r.p.m. is, however, only attained at 74.5 m.p.h. with the express locomotive, while it is reached at 40.5 m.p.h. with the freight locomotives. The complete motor weighs 6.2 tons.

Lifting plant for handling bulk materials and packages. It often happens that the same lifting plant has to be used either with a grab, for handling bulk materials such as coal, sand, gravel, etc., or with a hook, for dealing with packages. In such cases, grab and hook must be easily interchangeable. When use is made of a single-rope grab, the changing over of suspension gear can be easily effected and only requires little time. With two-rope grabs, however, which are very widely used, owing to the great advantage they present over single-rope grabs of permitting of the unloading of materials from any desired height, this operation is somewhat difficult to carry out and, in the case of certain designs, even impossible. In view of this, the Oerlikon Company, when designing their standard two-rope grabs, have paid special attention to the question of easy and simple interchangeability of suspension gear. Figs. 1, 2 and 3, show the arrangement adopted for ropes and the method of fastening them. Fig. 1, is a diagrammatical representation of a two-rope grab, Fig. 2 shows a hook with cross-head and Fig. 3 is an enlarged view of the equalising device for the lifting ropes. In these illustrations, (a) designates the opening ropes and (b) the lifting ropes; as can be seen, the opening ropes (a) can be easily released. As regards the lifting ropes (b), they are secured at their end, to the equalising device (d), by means of a wedge (c); the arrangement is clearly shown in Fig. 3. As a result of this mode of fastening, the lifting ropes can also be easily detached. When the grab or the hook equipment has been lowered to the ground and the lifting ropes are loose, the wedges (c) can be easily driven out and the ropes pulled off. The method resorted to for fastening the ropes to the cross-head of hook can be clearly seen from Fig. 2. With average sizes of gear, changing over from grab to hook or vice-versa occupies at the most 15 minutes.





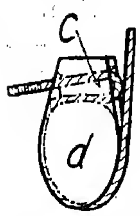
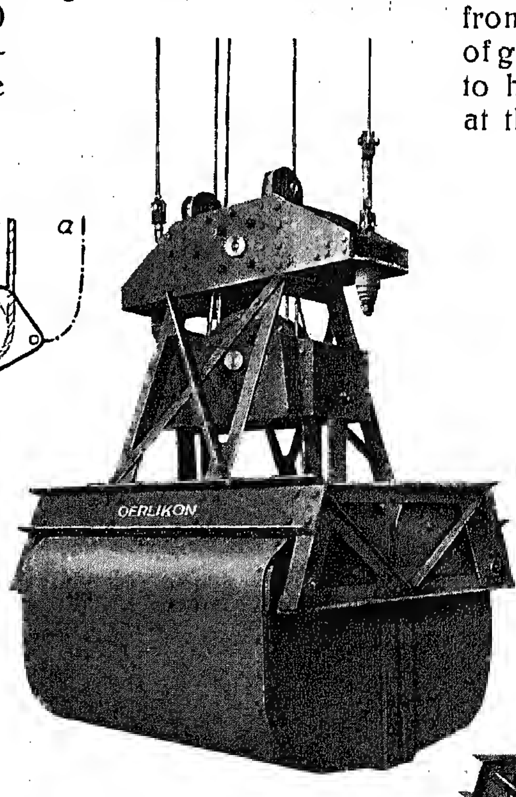


Fig. 1—3. Method of fastening the ropes on the Oerlikon two-rope grabs.



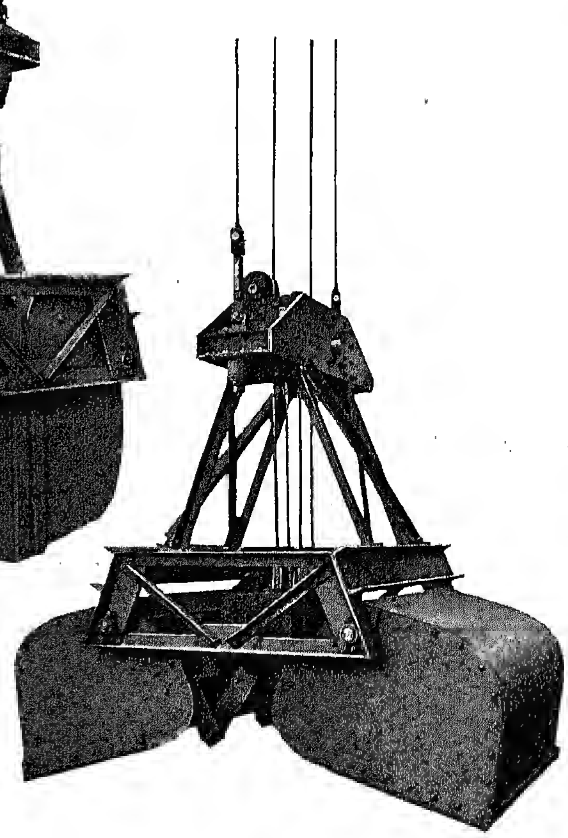


Fig. 4—5. Two-rope grabs of standard design for a capacity of 88 cu. ft.

BULLETIN OERLIKON

No. 65 — November 1926

Contents:

The Electric Locomotives of the Bernese Oberland Railway.

The Bernese Oberland Railway serves to connect the town of Interlaken with the mountain resorts of Lauterbrunnen and Grindelwald; it starts from Interlaken-East and rises to Zweiluetschinen, where the lines to Lauterbrunnen and Grindelwald branch off. The section Interlaken-Zweiluetschinen has a maximum gradient of 1 in 40 and is for adhesive operation only, while the two branch lines from Zweiluetschinen to Lauterbrunnen and Grindelwald, which have gradients reaching 1 in 11.1 and 1 in 8.5 respectively, include also rack sections.

The Bernese Oberland Railway was opened in 1890 and operated by steam up to 1914, when it was converted to electric traction. The work of electrification was completed shortly before the outbreak of the war, eight electric locomotives being provided to ensure the service. The four years of the war and the unsettled conditions which followed hit all transport undertakings very severely, and more especially those which, like the Bernese Oberland Railway, depended mainly on tourist traffic.

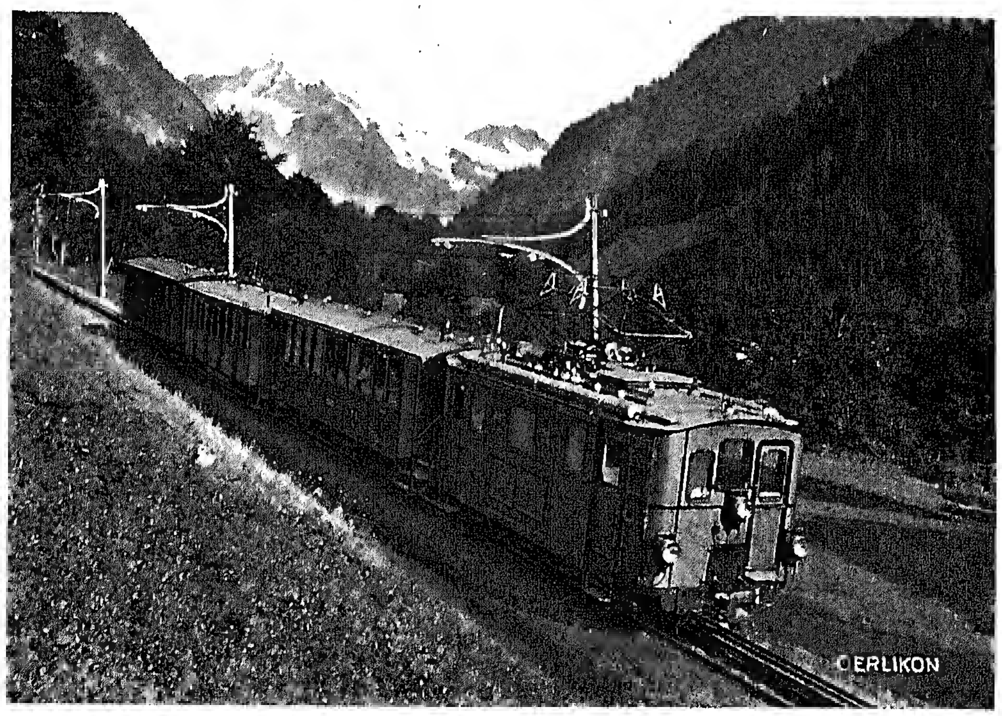


Fig. 1. Train of the Bernese Oberland Rly. hauled by locomotive No. 29.

After 1923, the number of visitors showed again a tendency to increase and, in 1925, the pre-war figures were actually exceeded. It was then found that the traffic could no longer be dealt with by the eight electric locomotives, even when putting into service the standby steam locomotive; for this reason, and in view of the gradual improvement in the financial situation, the railway authorities decided to order, provisionally, one further electric locomotive, the contract for the complete electrical equipment of the latter being secured by the Oerlikon Company who had already supplied the motors for the first eight electric locomotives. The mechanical part of this locomotive (No. 29) was built by the Locomotive Works of Winterthur, as in the case of the former ones. The new locomotive was put into service in the middle of July 1926. Although the locomotive is similar, in many respects, to those formerly supplied, it embodies in its design several new features, which we shall describe further on. All locomotives are for rack and adhesion operation. The traction system adopted on the Bernese Oberland Railway is 1500 volts D. C., the current being supplied from a substation situated at the Zweiluetschinen junction.

All three driving axles are coupled together. Apart from the driving rack pinion, there is also a braking pinion, which is mounted on one of the driving axles about which it can revolve freely. The two motors are mounted on the frame of locomotive and work through double reduction gears. In the case of the old locomotives, the gear ratio is the same for both modes of operation. On the new locomotive, however, gear ratios of 1:4.26 for adhesion operation and of 1:6 for rack operation have been adopted, as it has been found that such ratios with different values were preferable, in order to prevent the skidding of driving wheels, when travelling on rack sections. In the case of adhesion operation, the torque is transmitted from the reduction gear to the three driving axles through the intermediary of a jack shaft and connecting rods.

The body of locomotive is arranged with enclosed driver's cab at either end, and compartment for motors, control gear, and starting and braking resistances, in between. A passage is provided on one side of the motor compartment, while hinged doors at either end give access to the driver's cabs. The starting and braking resistances are secured to the central part of roof, which is removable; consequently, once that part of the roof has been raised together with the resistances, the motors can be easily lifted out and replaced.

The driver's cabs are provided on either side with a door leading outside, while there is also a communication door arranged in the front part. The following mechanical brakes are fitted on the locomotives: 1 hand operated brake acting on the wheels, 1 hand operated rack brake, 1 West-

inghouse combined adhesion and rack brake, 1 automatic speed limiting brake, built as a band brake and worked by compressed air, which comes into play when the speed exceeds normal speed by 20%, on steep inclines. The electrical equipment of the new locomotive presents several improvements as compared with the 8 old locomotives, with respect to motors and apparatus; the following are a few particulars regarding the equipment in question.

The two driving motors are of the four-pole type; they are fitted with interpoles and provided with very powerful self-ventilation. Both motors are identical as regards electrical design, and, apart from their having reduction gears with different ratios, are interchangeable. The one-hour rating of motors, measured at wheel rim, is 410 HP at 590 r. p. m., while the continuous rating is 310 HP at 630 r.p.m., as compared with 250 HP in the case of the old locomotives, these values being for a pressure of 1500 volts.

Length over buffers 27′ 0 7/16″
Length of body 23′ 9 1/16″
Height of roof above rails 10′ 5 5/16″
Width of body 9′ 0 1/4″
Gauge 3′ 3 3/8″
Rack system: "ladder" type rack
Pitch of rack 3 15/16″
Numb. of driv. axles 3
Numb. of driv. rack pinions 1
Diameter of driving wheels 2′ 11 13/16″
Diameter of pitch circle of driving rack pinion 2′ 9 7/8″
One-hour rating of motors, at wheel rim: 410 HP each at 1500 volts
Weight of locomot. 36.5 tons
Weight of electrical equipment 16.3 tons

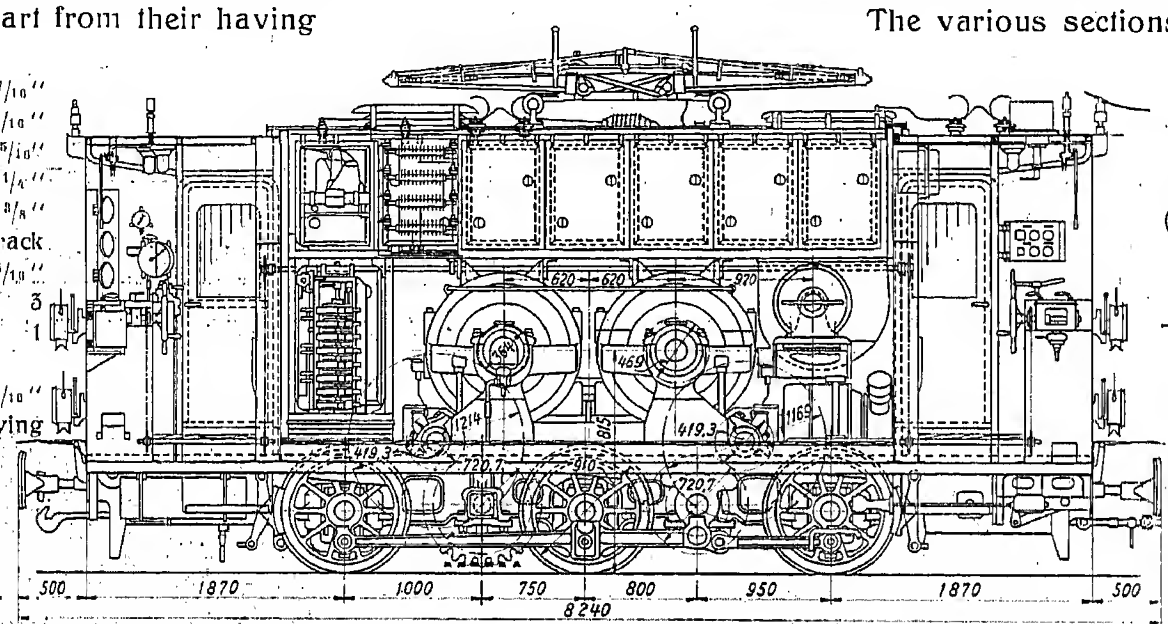


Fig. 2. Locomotive No. 29 of the Bernese Oberland Rly.

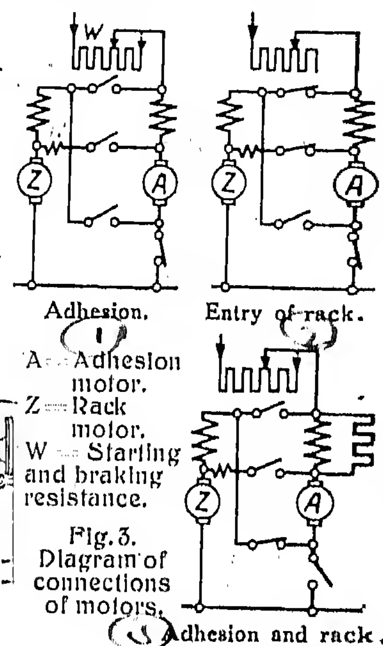


Fig. 3. Diagram of connections of motors.

The permissible trailing weight on the adhesion sections is 125 tons at a maximum speed of 25 m.p.h (40 km/hour). On the gradients of 1 in 11.1 and 1 in 8.3 of the rack sections, the locomotive can deal with trailing weights of 90 and 60 tons respectively, at a speed of 6.2 to 7.5 m.p.h. (10 to 12 km/hour). During the height of the season, two locomotives are coupled to the trains, in order to be able to haul twice the load in one journey.

The diagrams given in Fig. 3 show the mode of connection of motors on the different sections; as will be seen, when travelling on the adhesion sections, the "adhesion" motor alone is used. On entering rack sections, an intermediate mode of connection is adopted, where the two motors are in parallel and the starting resistance in series, the "rack" motor being brought automatically to the correct speed before the load is applied. As soon as the rack has been engaged, the two motors are connected in series, and the field of the adhesion motor is shunted.

During downgrade operation, the whole train weight is dealt with by means of electric braking, in which case the motors work on resistances, use being made for this purpose of the starting resistance supplemented by additional resistances. The new locomotive is fitted with cast iron resistances instead of the usual strip resistances, formerly used. The resistances in question are cooled by means of a small blower; the latter is coupled to an electric motor which also drives the L. T. dynamo for the lighting of locomotive.

The various sections of the starting resistances are cut in and out by means of a controller equipment with cam gear; this controller is operated mechanically from the driver's cab, by means of a handwheel, Gall's chain and extended spindle.

The other gear, such as pantograph current collector, automatic main circuit breaker, direction changer and motor reverser for adhesion and rack operation, is operated by means of compressed air at 85 to 115 lbs/sq. in. Control valves with suitable handles are provided for this gear, on the controller plate in driver's cab, and arranged in such a way as to permit of easy supervision. The whole H. T. apparatus has been designed to meet the special requirements of the Bernese Oberland Railway and has proved entirely suited for the purpose and very reliable in operation. The electric heating circuit of locomotive is connected to the 1500 volt supply, while the current for the lighting of locomotive is supplied at 110 volts by the dynamo referred to above. On the other hand, provision is made for a hand-operated circuit breaker fitted with magnetic blow-out and designed for a breaking capacity of 150 KW, for controlling the

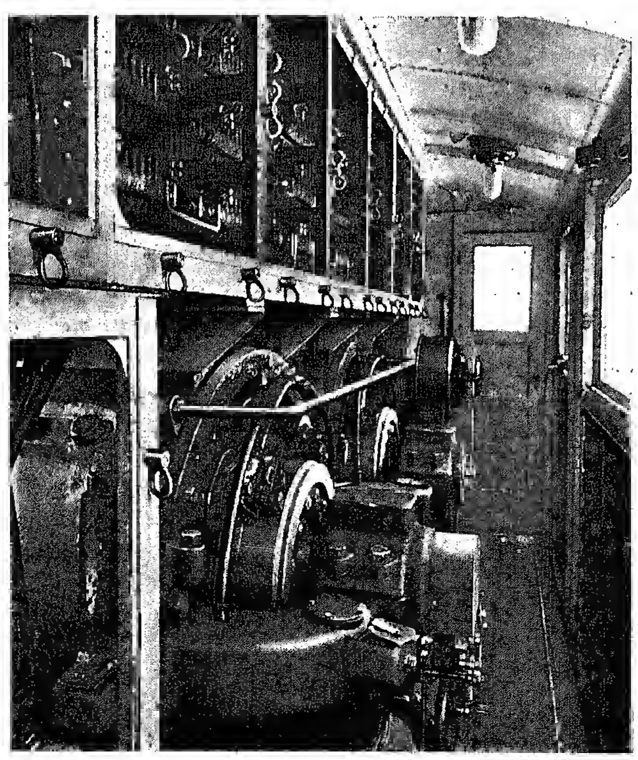


Fig. 4. Side passage in locomotive No. 29; on the top, resistances with cover removed.

1500 volt heating circuit of train; there is further a motor-operated compressor for 85 to 115 lbs/sq. in., for supplying the compressed air required for train braking purpose, as well as for the operation of control gear and master switches.

Notes and News Items.

New electric locomotives for India and Spain. The Oerlikon Company have, during the past months, met with further success in the field of electric locomotives. Mention can be made, in the first place, of the trial express locomotive ordered by the Great Indian Peninsular Railway Co. from the General Electric Co. Ltd. The electrical equipment of this locomotive (Fig. 1) is being built by the latter firm, under licence, to the designs of the Oerlikon Company, and the mechanical part is being supplied by British locomotive makers. The locomotive is to be designed for a continuous output of 2160 HP at wheel rim, and 1400 volts D. C. at overhead line, the speed being 55 m. p. h.; this corresponds to a continuous tractive effort of 25000 lbs. at wheel rim. The maximum speed is 85 m. p. h. The locomotive is of the 2C2 type, and arranged for individual drive; each of the three driving axles is driven by a twin motor, through the intermediary of a quill. The torque is transmitted from the quill to the wheels by means of the special Oerlikon flexible axle drive. The locomotive is controlled by contactor gear. In the case of each of the three methods of grouping of motors, the field is weakened in two steps.

On the other hand, the Oerlikon Company has recently received an important order for 22 electric locomotives of the C+C type (Fig. 2) from the Spanish Northern Railway. These locomotives are also for high tension D. C., the pressure here being 1500 volts at overhead line; the control is equally ensured by means of contactor gear. The two six-wheel bogies are tight coupled and each axle is driven by a separate motor, the latter being arranged for "tram" suspension. The one-hour rating of locomotive is 2040 HP, at wheel rim, at 20.5 m. p. h.; this corresponds to a tractive effort of 36800 lbs. The maximum speed is 56 m. p. h. Provision is made, here also, for the weakening of field during series and parallel operation; furthermore, the locomotives are being arranged for the Oerlikon method of regenerative braking.

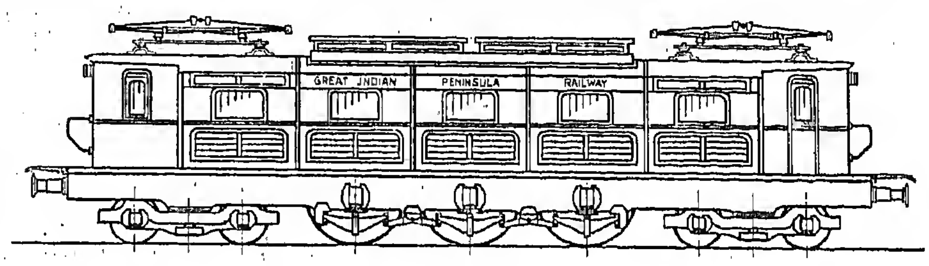


Fig. 1.

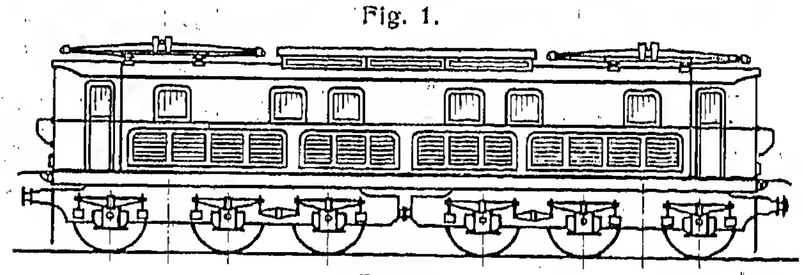


Fig. 2.

Emergency device for tramcars for one-man operation. The Oerlikon Company have devoted considerable attention to the question of emergency devices for use on tramcars for one-man operation. After carrying out very exhaustive tests in this connection, they have been successful in evolving an appliance which can be regarded as one of the most effective of its kind. The object of this safety device is to apply the brakes and bring the tramcar automatically to a standstill in the shortest time, in the event of the driver becoming helpless or of his losing control of the vehicle, for any reason. As it may then also be necessary, in certain cases, for the passengers to be able to apply the emergency brake, themselves, suitable operating gear has to be provided in the interior of tramcar as well.

These various conditions have been complied with, on the one hand, by fitting a step-back device on both controllers and, on the other hand, by providing, along the interior of tramcar, emergency handles, which are mechanically coupled to the step-back devices, the arrangement adopted being specially suited for the duties in question, and thoroughly reliable in operation. The step-back device is mounted direct on the controller; it comprises an operating spindle coupled to the controller spindle by means of a clutch, a step-back spring normally held in a compressed position by an internal nose, but brought into play as soon as the clutch is released, and the "dead man's handle" device on the controller. Under ordinary running conditions, the handle of controller must constantly be held down in a horizontal position, the pressure to be applied for this purpose being about 4 lbs.; there is no danger of this causing too much fatigue to the driver as the torque to be exerted for the switching operations is no greater than in the case of an ordinary controller. If the handle is released the spindle is uncoupled, the spring comes into play and the controller drum is brought back to the last braking position (emergency braking); as a result, electric braking is brought into operation, and the rail brakes of tramcar and of trailer, if any, are energised. The same process takes place if the emergency handles in the tramcar are drawn, the controller handle being then released by means of a cable. The spring is compressed again merely through the action of bringing back the controller handle to the last braking position, while it is held in a state of compression by depressing the handle; after this, the controller is ready for starting anew the switching process.

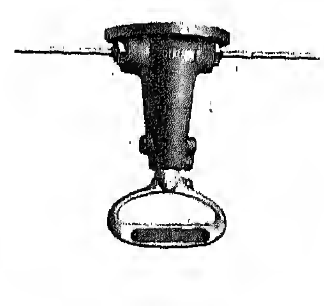


Fig. 1. Emergency handle.

It may further be mentioned that, by depressing a foot lever arranged at the floor level, the direct release of controller, which would otherwise take place when letting go of the handle, can be prevented in any position; this enables the driver to have the use of both hands, when giving change for fares, for instance. The indirect release by means of the emergency handles in the tramcar is, however, not affected and remains ready to function.

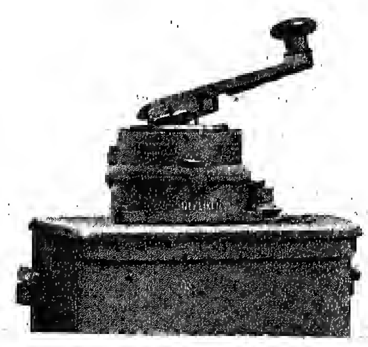


Fig. 2. Controller with step-back device.

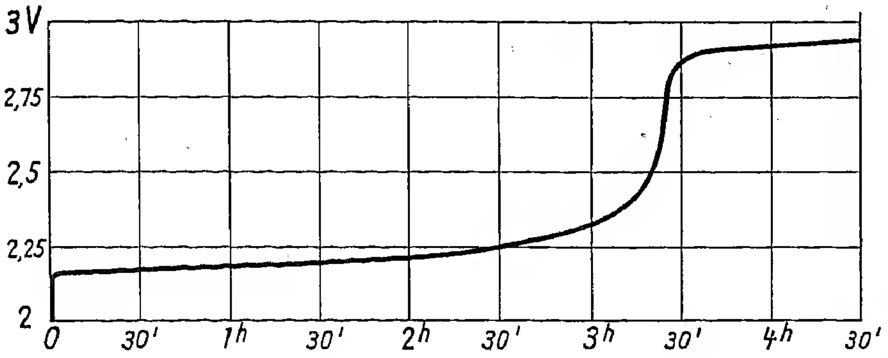
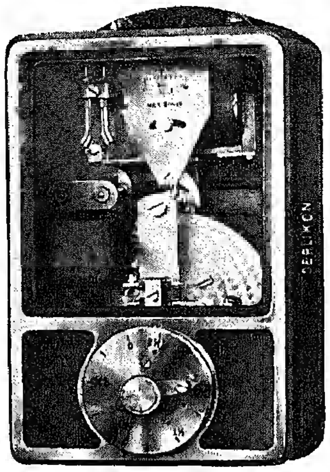
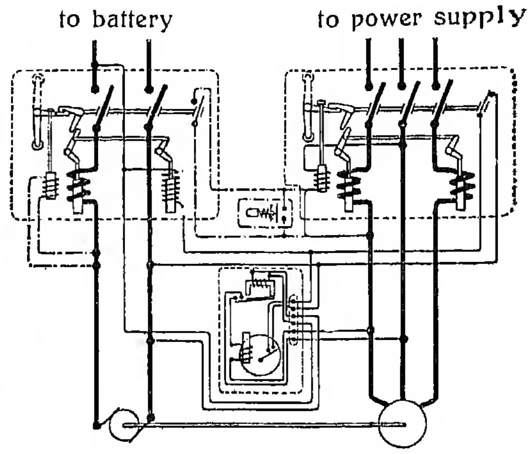


Fig. 1.





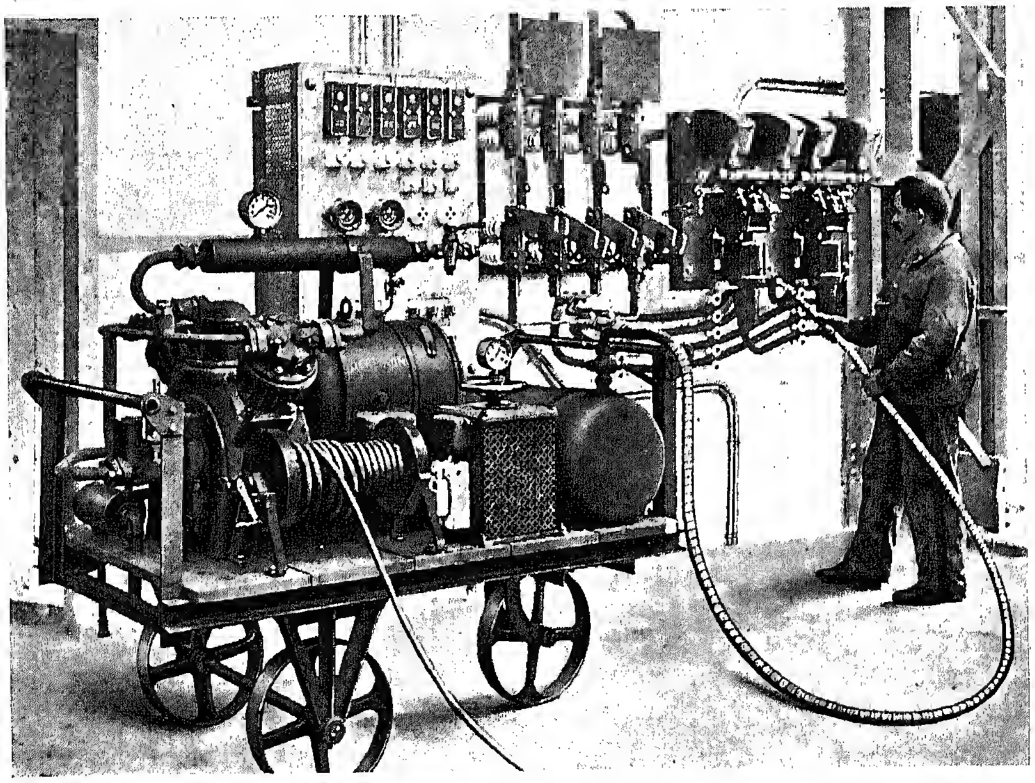
Figs. 2 and 3. Dynamo Motor

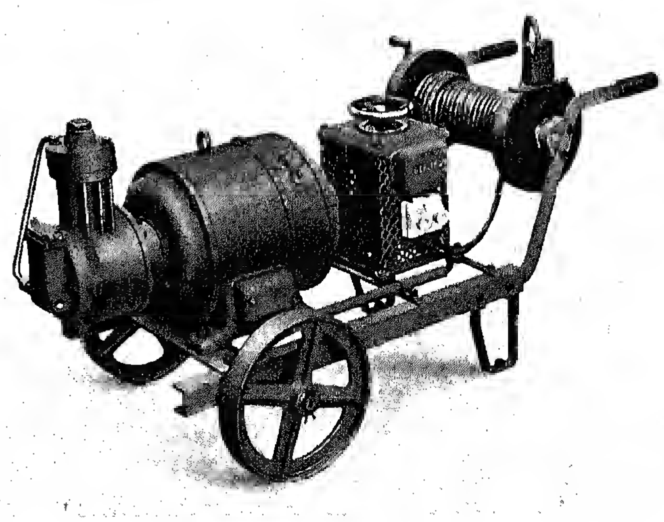
Charging relay for the automatic disconnecting of batteries at the end of charge. When batteries of accumulators are left unattended during charging, the extent of charge can be limited by arranging for the disconnecting of battery when the maximum end pressure is reached, by means of a special pressure relay adjusted for the conditions in question. This method which has been used by the Oerlikon Company, for a long time, presents certain advantages over the arrangement with minimum current and reverse current relays; there is, however, even then, a possibility of over-charging or under-charging. The new Oerlikon charging relay, on the other hand, affords a means of ensuring the complete charging of battery, under any conditions, without danger of over-charging. The method in question is based upon the fact that batteries of accumulators, after attaining a cell voltage of 2.4 volts (commencement of gassing), always require, from that point, the same time to reach full charge, this time being fixed by the characteristics of battery. As the charging curve is fairly steep in the neighbourhood of a cell voltage of 2.4 volts, as can be seen from Fig. 1, the relay can be adjusted very accurately at that pressure; these conditions do not, however, obtain when the relay is adjusted for the end pressure, as the curve is there very nearly flat. When the charging relay comes into play, it brings a time relay into operation, which can be set for a running-out time between half-an-hour and $2^1/_2$ hours, according to the conditions of service; the running-out time is practically independent of the temperature, and of the pressure fluctuations of the system feeding the coil of the time relay. The charging relay is arranged in a drip-proof casing, which also affords sufficient protection against acid vapours. Mechanism and contacts are clearly visible from the outside through a glass window. The running-out time of time relay can be adjusted without opening the cover.

Fig. 3 shows the mode of connection of an installation with such a charging relay.

The use of this new charging relay in battery installations means a further advance in battery practice, and must necessarily lead to an increase in the life of batteries.

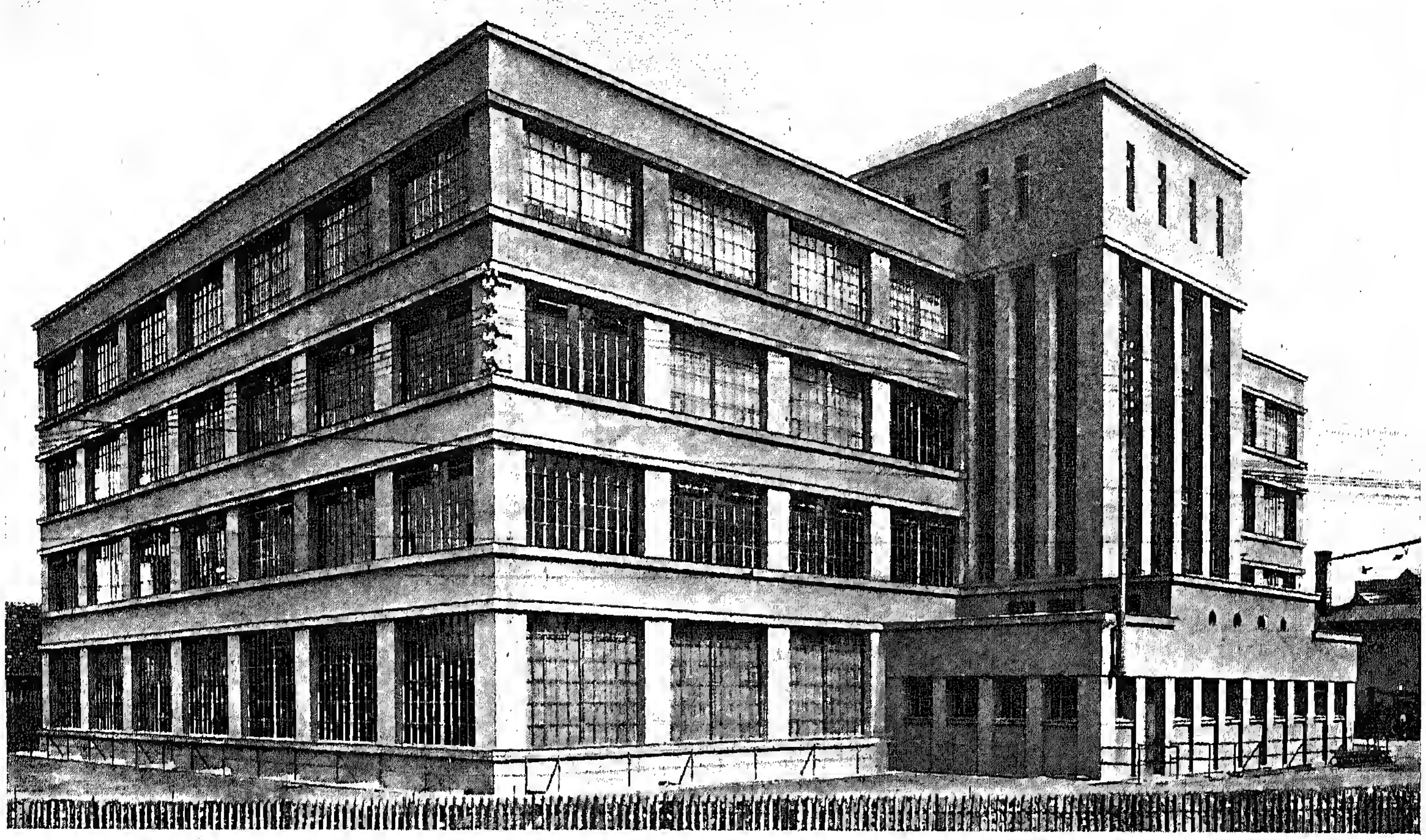
Portable compressors and vacuum pumps. Compressors and vacuum pumps are being used more and more in large power stations for various purposes. In order to meet the requirements of such installations, the Oerlikon Company have designed a combined compressor and vacuum pump mounted on truck. The illustration in the centre of this page shows an equipment of this type. The plant in question can be converted into a compressor or a vacuum pump merely by adjusting a three-way cock. The compressor is provided with an exhaust valve, which opens automatically when the pressure exceeds a certain value and closes again when the pressure in the compressed air tank drops below a certain value. A non-return valve eliminates all possibility of the compressed air flowing back out of the tank. A separator is inserted in the suction pipe with a view to preventing water from being drawn in. The second illustration shows a compressor set mounted on a light two-wheel truck.





BULLETIN OERLIKON

No. 66 — December 1926



View of the Switchgear Works, taken from a north-westerly direction (street side).

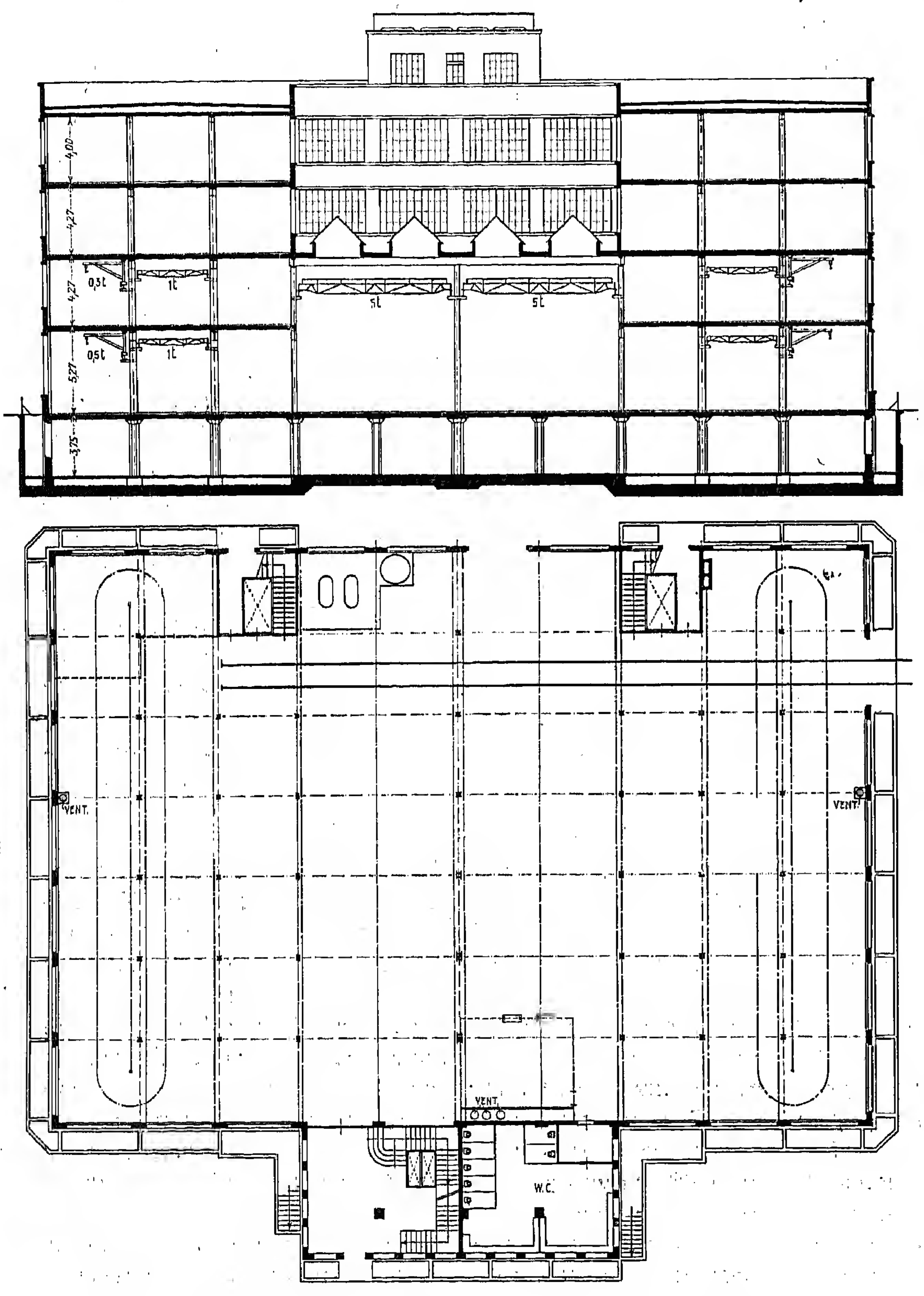
The Switchgear Works of the Oerlikon Company.

In view of the great developments which have taken place, in recent years, in the field of electrical apparatus, the Oerlikon Company have found it necessary to erect a new building in keeping with the importance of this branch of manufacture, where the various switchgear shops and drawing offices, previously distributed over various departments, are now concentrated. Work was started on these premises last year and progress was so rapid that it was possible to move into the new shops and offices in the course of the spring and summer of this year. The switchgear works in question are a combination of a storied building and of a shed structure, this design being adopted so as to permit of the manufacture of the largest circuit breakers as well as of the smallest apparatus, such as operating and supervisory relays, under the most favourable conditions.

The new building is situated on the border of the old factory site and faces the street; it is linked up with the other parts of the Oerlikon Works by a wide factory roadway and has its own street entrance with gate-keeper house. The building is designed in the shape of a horse-shoe, the inner part of which is occupied by the erection shed; the latter reaches up to the second floor, the height available under the crane, for the erection of gear, being 23 ft. The width of the building is 164 ft, while the wings have a length of 115 ft. The layout is such as to permit of the subsequent extension of the two wings, through the whole height of building, together with the erection shed in between. The total height of the building itself, excluding the basement, is about 65 ft. The basement, ground floor, and first and second floors are used for workshops, the top floor is utilised for offices.

The soil on which the building is erected is of irregular formation, and consists of gravel and sand deposit. As the ground water can rise above the level of the basement floor even during periods of average rainfall, it was necessary to take special measures in order to keep the rooms in the basement perfectly dry. In the first place, there could be no question of lowering the level of ground water, owing to the presence of sand and to its liability to be washed away. The difficulty was, however, overcome by erecting the building on a continuous base of reinforced concrete, which together with the outer walls of the lateral light shafts, is made water-tight by means of a special preparation. In order to ensure an effective stiffening of foundations, the whole basement, including the supporting walls, the columns and the light shafts, is

made of uniform reinforced concrete construction, some 172 tons of iron and 56500 cu. ft. of concrete being used for the purpose. The floor of the basement is about 2 ft. 3 ins. above the surface of the concrete foundations and the space in between is utilised for accommodating the drain pipes and the ducts for heating and ventilation. The ceiling of the basement has no supporting beams but is carried by columns with very



Sectional elevation and plan of the switchgear works. Scale 1:500.

wide conical capitals; in this way, both visibility and space are increased. The main body of building is of iron construction throughout from the top of basement upwards. The walls consist of masonry work, in which the metallic structure is encased. The two wings are linked up together at the level of the second and third floor by rooms built over the erection shed; as a result, an additional floor space of 6450 sq. ft. is obtained, without this affecting in any way the lighting of the shed. About 600 tons of iron were used for the structural work of building. In order not to encroach on the space of the shops and offices, and thus permit of better room conditions, and easier supervision, the main staircases are arranged in a separate tower; the latter, which reaches above the top storey, and is situated on the side of building facing the street, in the centre, contains also two passenger lifts, the lavatories and the central room for fans and warm water boilers. There are also further staircases as well as goods lift at the end of each wing.

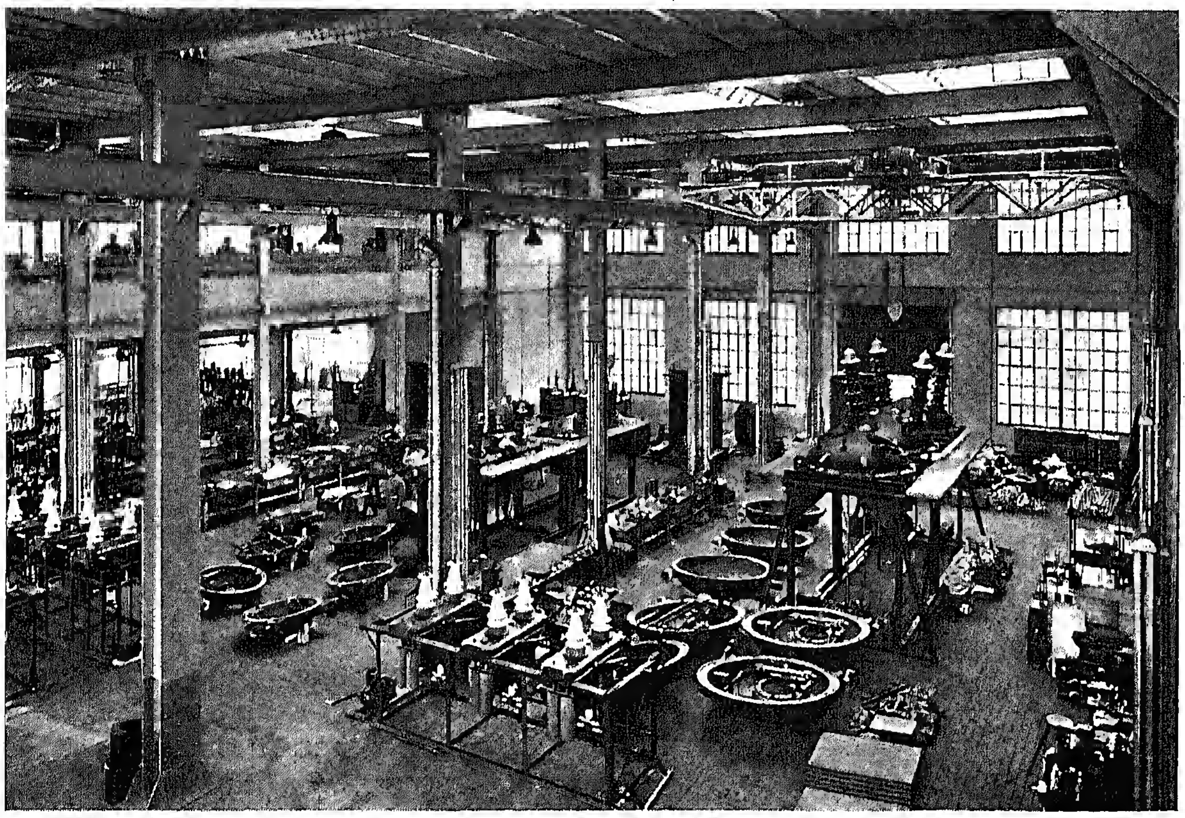
The parallel character of the different storeys is accentuated by the long rows of windows of uniform design which intersect the walls, and by the broad window sills which encircle the whole building, while the predominant feature of the tower is the vertical subdivision of its walls. In spite of this formal contrast between the design of the main body of building and the tower, which emphasises their respective purposes, the result is quite pleasing from an aesthetical point of view. The intermediate floors of building are made of iron framework, with cement slabs in between, the whole being covered with a layer of concrete; with this design it is easy to make subsequent structural alteration or to cut openings in the floor for pipes etc. The following are the floor coverings used in the various parts of the building: asphalt in the basement, wood blocks embedded in asphalt in the workshops, tiles in the lavatories and lino in the offices. The roof is designed with insulating air space and is rendered watertight by means of a special preparation. The heating of the building is ensured by means of a warm water central heating system, with circulating pump. The forced ventilation of the basement rooms is ensured by the fan sets provided in each wing, which also supply fresh air to the different shops, though ducts run throughout the different floors.

The switchgear works are, at present, provided for about 500 workmen, the latter being distributed over the basement, ground floor and first and second floor; the top floor which, together with the room over the erection shed, has an area of about 15,600 sq. ft. is used for offices; this part of the building contains all the drawing offices for apparatus and switchboards. The following process rooms are located in the basement:—

1. The galvanising room. The equipment in this room comprises all the different metal baths for galvanising and for plating with copper, nickel and silver; there is further a large conveyor bath for accelerated metal plating of articles produced in great quantities and also a tilting zinc bath for

intensive and rapid plating with zinc. On the other hand, a large zinc bath is provided for large and cumbersome parts. The installation further includes an equipment for de-greasing metal parts by the galvanic process and, finally, plant for de-greasing metal parts by subjecting them to the action of lime water in drums. The necessary low tension D. C. supply is derived from two motor generator sets, which are only used for the above processes. A neighbouring room contains milling and polishing plant. Both rooms, in addition to having large windows, are also provided with forced ventilation. The bad air is drawn away by suction plant so designed as to permit of the adjustment of draught.

2. Pickling Room. All metal parts whether they come from the foundry, the stamping shop or the pressing shop, must, nearly without exception, be pickled for the purpose of removing the inflammable layer at their surface or in order to obtain a bright appearance. The pickling is done, as a rule, with nitric acid, or with a mixture of nitric and sulphuric acid. These pickling solutions, which cannot be diluted too much, give out fumes very dangerous for the human organism; in view of this, pickling was done, as a rule, in former days, in the open. Later on, certain installations were built where the operator stood outside the actual pickling room and handled the articles to be treated with levers and remote controlled lifting gear. This arrangement has, however, proved in practice, to be too inconvenient and to entail a great reduction in output. The pickling plant at the Oerlikon switchgear works is also in the basement; the vats containing the acids are, there, entirely covered while special ejectors operated by means of water under pressure, carry away the dangerous gases and vapours. In this way, it is possible for the operator to stand in front of the vats without danger and carry out his work easily. The basement further includes a room for the oil-blacking process, and a shop for assembling metallic fittings on porcelain insulators. All the basement rooms have, in spite of their low level, plenty of daylight; the heating is ensured by means of a combined system of warm air and warm water heating, while gas, water (hot and cold) and electric lighting and power mains are laid through out the basement.

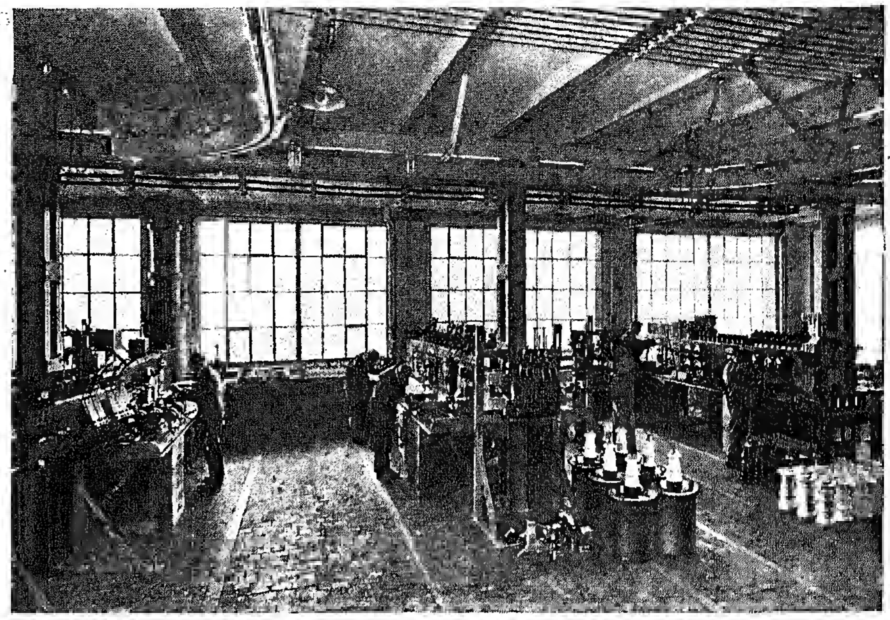


Erection shed on ground floor; on the left, above, erection shop for traction apparatus.

The ground floor, which has an area of 18,850 sq. ft., accommodates in the right wing the milling, drilling, stamping and pressing shops. The machines are driven in groups by electric motors. When disposing the plant, an arrangement was adopted such as would permit of the installation, at a later date, of a belt conveyor for serving the machines. The left wing contains the switchboard shop and erection shop for oil circuit breakers, for which considerable head room is often required for erection purposes. The height of the ground floor shops in the wings is 17 ft. 3 in.; there is further, as stated before, a central erection shed, specially provided for the erection of large equipments. The height available there, between floor and level of crane runway, is 24 ft. 10 ins. This shed has two bays and each bay is served, at the present time, by an electric 5-ton crane operated from the floor level. A standard gauge track connected to the system of the Oerlikon Works is laid in the erection shed, so as to permit of the loading of manufactured goods on the railway trucks and of the unloading of the heavy castings, boilers, etc., in the shed itself; the oil circuit breaker shop includes a testing installation where the H. T. gear can be subjected to pressures up to 350,000 volts to earth. Furthermore, there is a heavy current motor generator set for 5000 amps and 5 volts, for the testing and calibration of D. C. apparatus. For the calibration of heavy current A. C. gear and for the purpose of studying the effect of heavy currents on apparatus and contact gear, use is made of a transformer having a continuous rating of 20,000 amps and capable of dealing with peak loads of about 60,000 amps.

The first floor accommodates, on one side, the turning shop and, on the other side, the erection shop for traction apparatus. These two shops are connected by a gallery, arranged on the west side of the erection shed; this gallery is provided with two loading platforms, which can still be served by the shed cranes. The second floor is entirely used for the manufacture of small parts and apparatus, and relays. The test room of the apparatus department is also situated on the same floor. In view of the very wide range of gear manufactured, this test room is laid out on very com-

Drawing office on top floor (3rd), south-west portion.



Test room of apparatus department, on 2nd floor.

prehensive lines. All the different current supplies derived from the various generating sets are brought on to the panel of each test bench, and it is possible, merely by inserting a plug, to connect any of the sources of current to the working terminals, through regulating resistances, step transformer or induction regulator. The equipment fitted on the test benches includes, apart from this regulating gear, all the instruments most generally required. On the other hand, provision has been made for the measuring of resistances, testing of current transformers, as well as for insulation tests. Mains are also run from each source of current to the test-room in the oil circuit breaker shop, so as to permit of the testing, there, of the gear which cannot be transported to the apparatus test room, owing to its size.

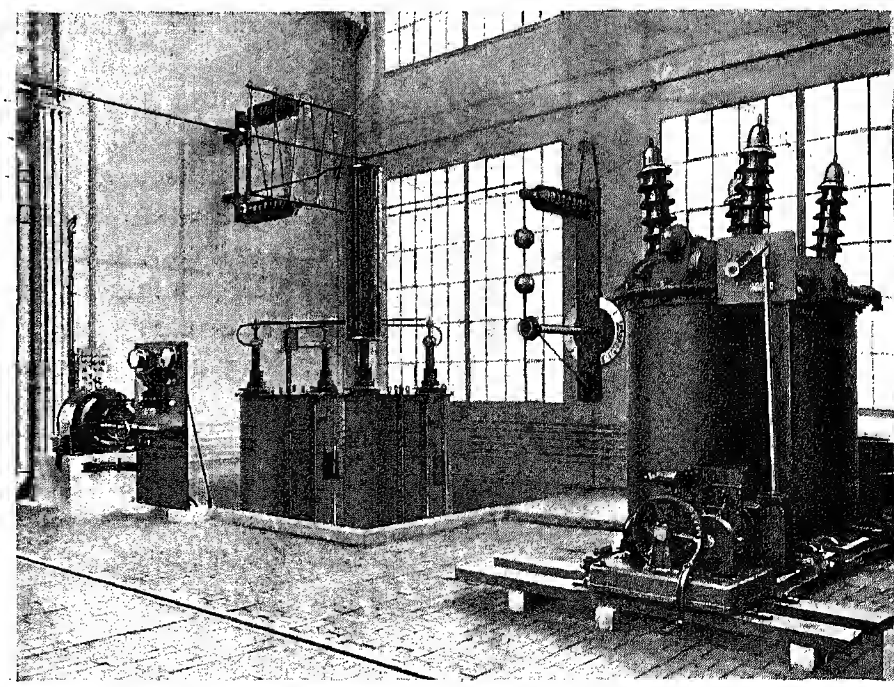
Hot and cold water, as well as gas, compressed air and electric light and power are available in all the workshop floors, while a connection with the oil mains is provided in the ground floor, through which the oil for filling the circuit breakers can be drawn directly from the storage tanks. The whole building has its own warm water heating system with circulating pump.

The materials for manufacturing purposes are supplied to the workshops, and the completed articles removed by the two goods lifts which serve all floors. These lifts are so dimensioned as to be able to take the electric trolleys, used for the transport of materials, consequently, there is no need to unload and reload the materials between the stores and workshops as the electric trolleys convey the goods direct to the place where they are required.

As regards the top floor, it accommodates all the technical offices. The main entrance of the building is in the tower, which contains the two passenger lifts for the use of the staff. There are further, at the end of the wings, staircases, as stated before. In spite of the fact that offices are directly below the roof, they do not get too hot in summer, as they are protected from the heat of the sun, by the insulating space provided. On the other hand, the visibility in the offices is very good, owing to the latter being at the top of the building.

The workmen's dressing rooms are located in the basement; each workman has washing facilities, there, and a locker for his use. These dressing rooms are reached by two staircases on the side of the tower. When coming in, the workman goes down into the basement by these stairs, and passes to the dressing-room. He changes his clothes there, and uses the stairs in the wing, on the same side as his dressing room, for getting to his workshops. When leaving work, he makes the same journey in the opposite direction.

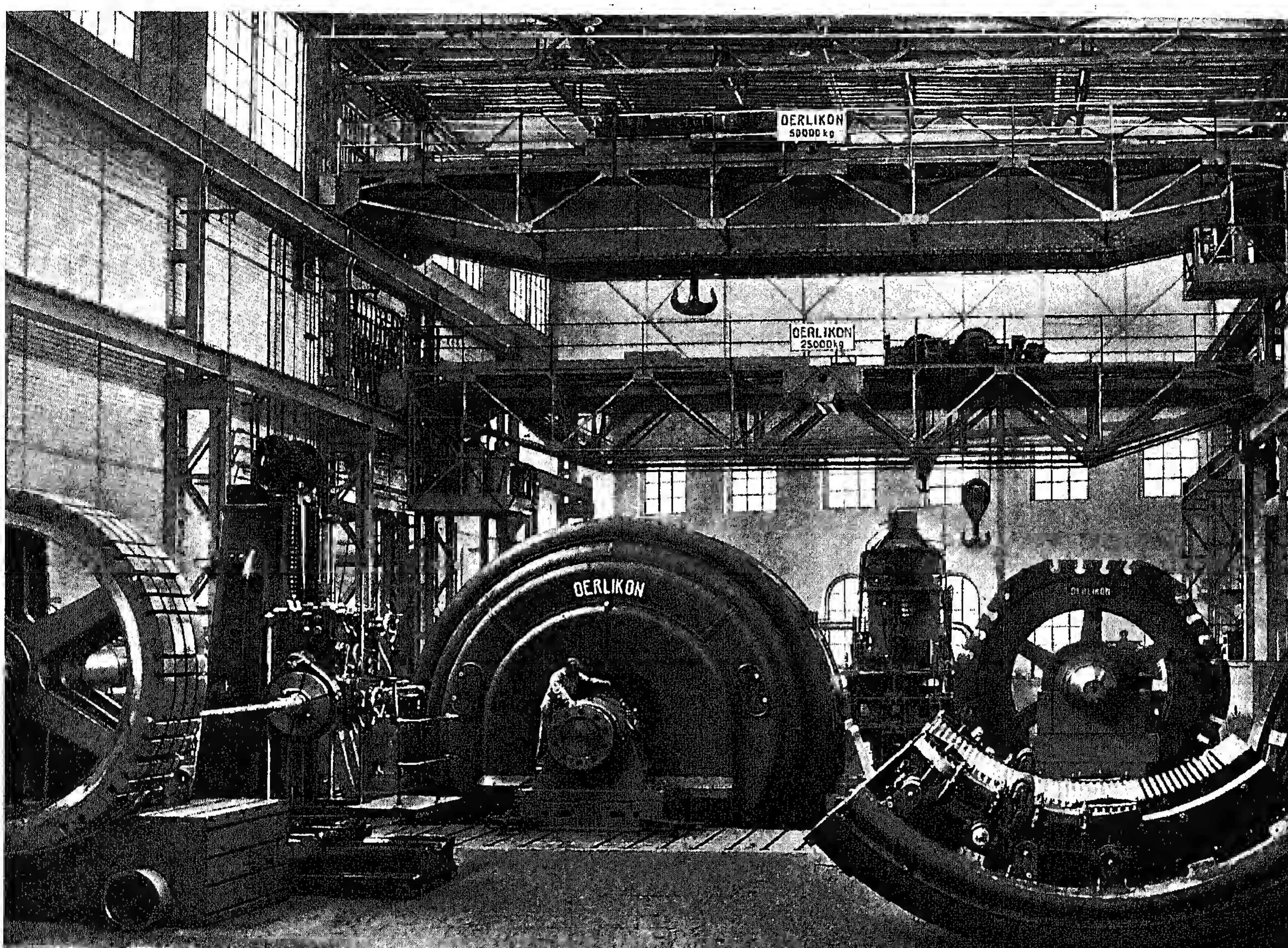
In conclusion, it may be said that the various advantages derived from the centralising of the different switchgear departments, and, in particular, the better facilities for supervising the manufacture of goods, as well as the more favourable lay-out of the shops and offices, must necessarily lead not only to a reduction in cost of production, but also further improvement in quality of goods. These are the considerations which have been the determining factors when deciding upon the heavy expenditure entailed by the construction of the new switchgear works.



Test bed for large apparatus on ground floor.

BULLETIN OERLIKON

No. 67 — January 1927

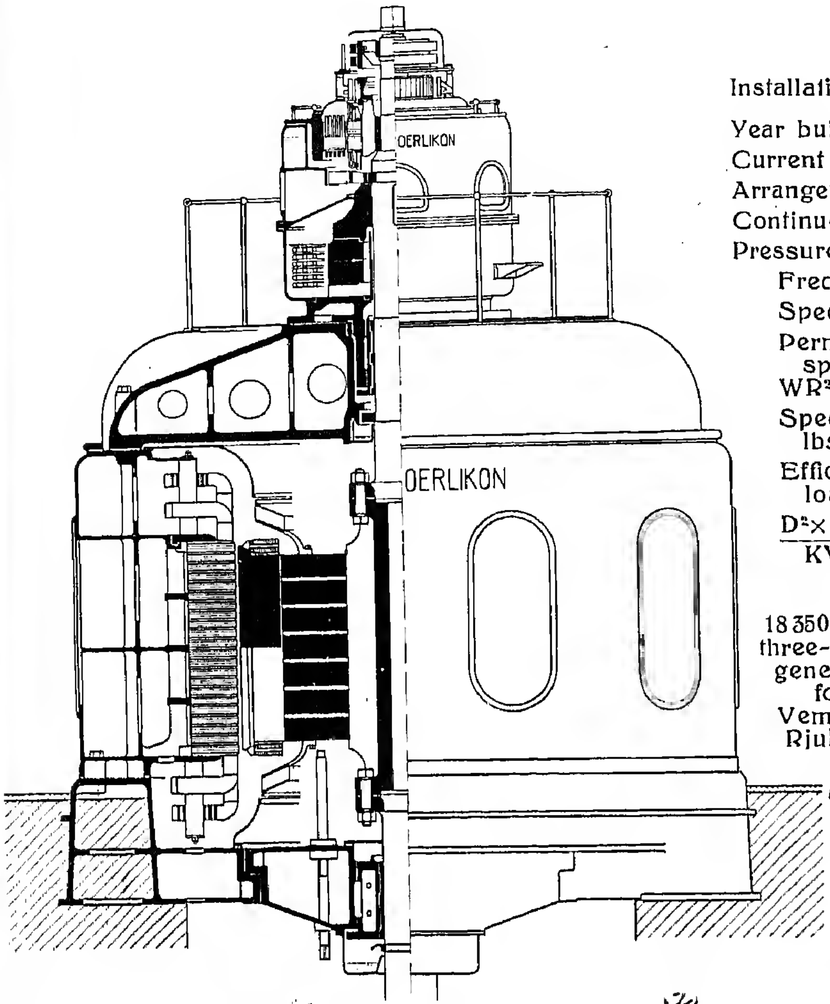


Single-phase generator for the Vernayaz power station of the Swiss Federal Railways.

Some Large Generators, Transformers and Circuit Breakers built in Recent Years by the Oerlikon Company.

The data collected by the Swiss Federal Polytechnical School for the International Inland Navigation Exhibition of 1926, in Basle, with regard to the development of plant for hydro-electric power stations give, in particular, an interesting representation of some typical features of the generators, transformers and switchgear built in Switzerland during the course of the year. A further valuable contribution to the subject is the report of Prof. W. Wyssling on electrical equipments of Swiss manufacture for hydro-electric installations. In this connection, it may be said that no small portion of the power station plant in question has been supplied by the Oerlikon Company; this firm was in fact one of the first to take up the manufacture of electric machines and apparatus and has now over forty years experience in this field. In addition to supplying these machines for Swiss power stations, the Oerlikon Company have always taken a considerable part in the export trade, and many of their most interesting designs have been produced for installations in other countries, without any description of the plants being published. It may therefore be of interest to give particulars of some typical units built in recent years. For the sake of completeness, the machines already referred to at Basle are also included in the following list.

The development of the design of generators for coupling to water turbines has been more especially in the direction of better utilisation of material, the results attained in this



18 350 KVA three-phase generator for Vemork-Rjukan.
Norway

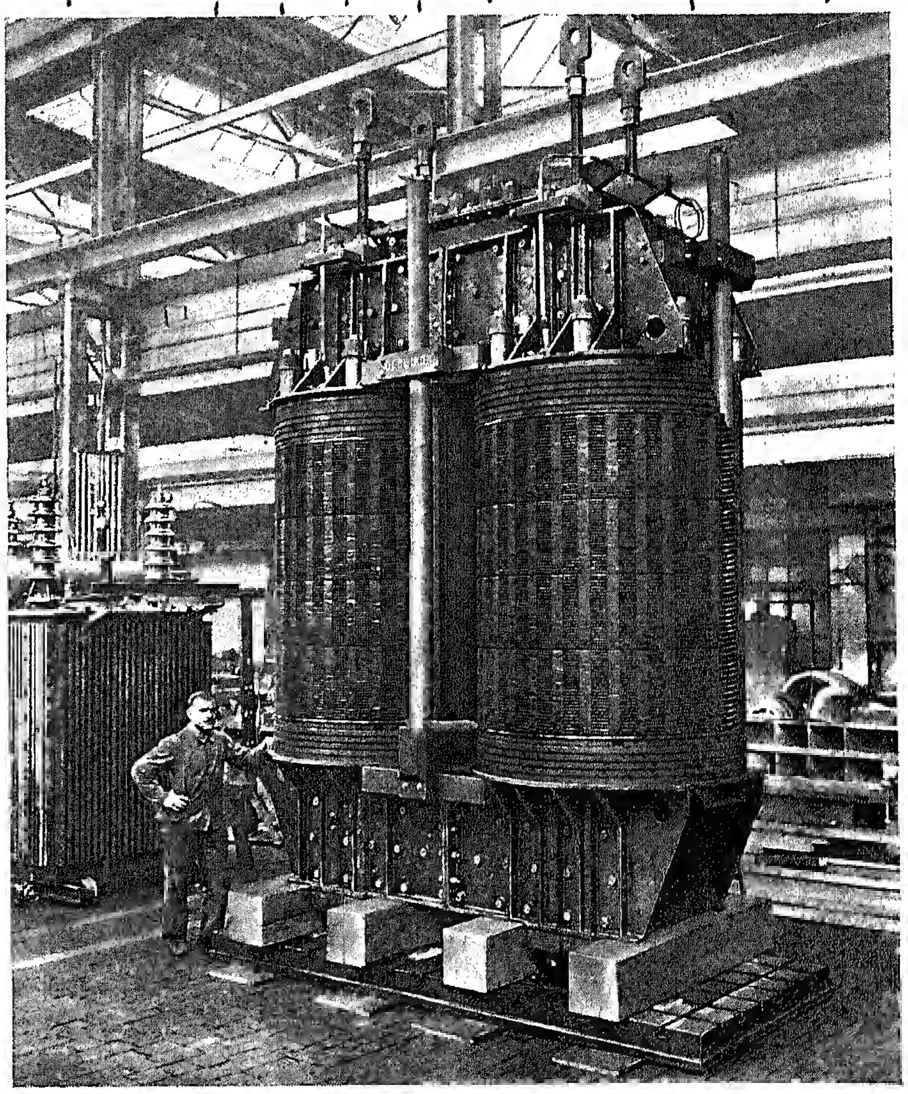
I) Oerlikon generators for coupling to water turbines.

Installation	Vemork	Catalana	Eglisau	Bramanger	Solbergfos	Siebnen	Tourtemagne	Meran	Vernayaz	Vemork	Mendalan	Vernayaz
Year built	1914	1916	1919	1921	1922	1923	1924	1924	1926	1926	1926	1926
Current system	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	1-ph
Arrangement of shaft	hor.	hor.	vert.	hor.	vert.	vert.	hor.	hor.	hor.	vert.	hor.	hor.
Continuous rating, KVA	17000	9000	5150	8000	10000	16500	8000	9400	14000	18350	7000	11000
Pressure in volts	11000	6500	8500	12000	10500	8800	9500	10000	10000	11000	6000	15000
Frequency, cycles	50	50	50	50	50	50	50	42	50	50	50	$16^2/_3$
Speed, r. p. m.	250	500	83,3	250	150	500	750	420	$333^1/_3$	600	750	$333^1/_3$
Permissible over-speed	450	900	208	450	270	1000	1350	900	630	1100	1470	630
WR^2 in tons×ft²	223	39.6	281	53.7	221	28.1	56.2	25.2	81.6	26	6.38	114.6
Specific weight lbs/KVA	25.3	25.1	52.8	22.7	31.7	15.4	14.5	17.3	18	14.5	15.2	44
Efficiency, % of full load at P.F. = .7	95,5	95	93,5	95	95	96	96	95,5	95,5	96,2	95,5	94,5
$\frac{D^2 \times B \times r.p.m.}{KVA \times 10^4}$	35,9	46,3	39	31,9	33,4	31,4	30	27,5	31	28,5	31,6	55

connection being (1) reduction in weight and (2) increase in efficiency. This progress is, to a great extent, due to the intensive testing of material on a scientific basis during the years of shortage of material. The latest designs are thus the product of many years' experience and of modern research work.

In Switzerland, there has not been as large an increase in the size of units as in other countries and in America, in particular, owing to the special characteristics of water power. On the other hand, a greater number of medium size power developments are to be found there. The erection of such installations has been rendered possible, as a rule, through the adoption of so-called unattended automatic power stations. Synchronous induction machines are specially suited for such installations, as they can be started up, paralleled and closed down in the easiest possible way and can also be arranged for remote control. Such an installation equipped by the Oerlikon Company has been recently put into service and has given the best results; it is situated near Le Locle, the plant being entirely controlled from the main distributing station a few miles away.

In this connection, mention can also be made of the pumping installation of the Waeggi Valley power development, which serves for pumping the water of neighbouring streams into the storage lake, by making use of cheap night power, during the dry season; this installation is, like the automatic power station referred to above, intended for utilising small quantities of water power to assist a large power station. In this case too, special importance was attached to remote control, automatic starting up and synchronising; synchronous induction machines built by the Oerlikon Company were also used here. The plant consists of 4 vertical pump sets having



Single-phase transformer for the Rupperswil outdoor substation.

a continuous rating of 5000 HP and running at 750 r. p. m. A notable feature is that the efficiency of pumps is 80% and that of motors 96%. The speed is regulated according to the level of lake, so that the installation always works without throttling of pumps. In the case of surplus water, the motors are used as synchronous condensers for improving the power factor of system.

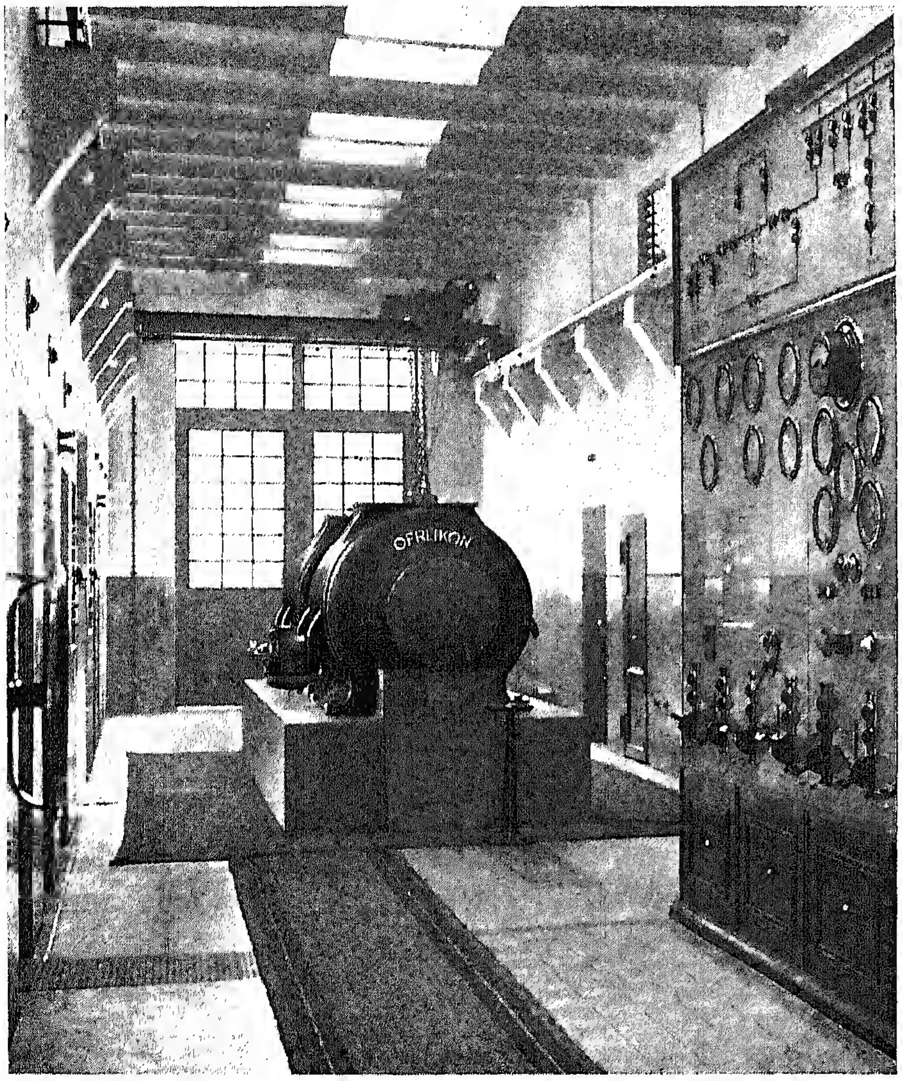
Economical considerations have, on the other hand, made it necessary, in recent times, to interconnect supply systems, in order to permit of the exchange of energy. The coupling of two power stations presents the greatest difficulties where the pressures of the two systems cannot be kept constant

II) Oerlikon transformers.

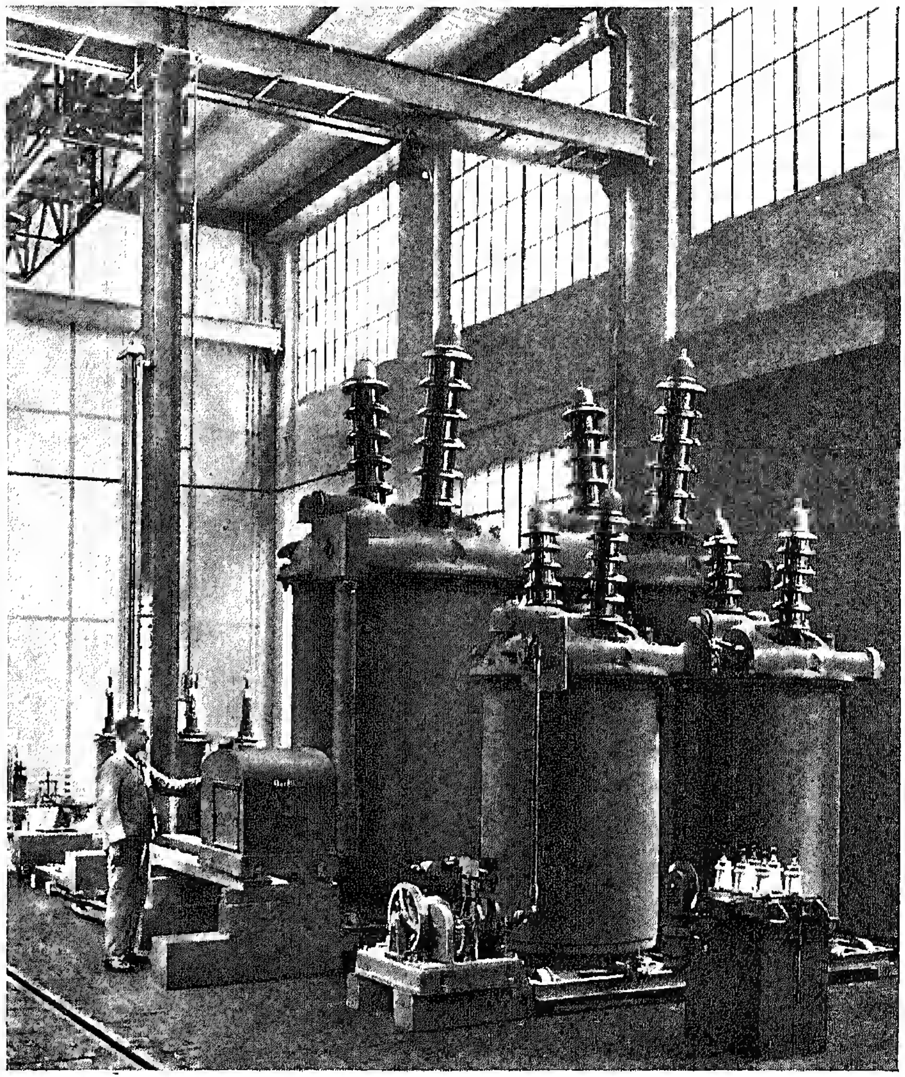
Installation	Anzin	Tafjord	Borgne	Küblis	Zurich	Burgdorf	Innsbruck	Joux	Barberine	Massaboden	Gossau	Ruppers-wil
Year built	1919	1920	1921	1922	1925	1926	1926	1926	1924	1926	1926	1926
Current system	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	3-ph	1-ph	1-ph	1-ph	1-ph
Continuous rating, KVA	12500	7300	8000	10000	5000	6000	3000	5000	10000	3000	3000	9000
High pressure, KV	47	114	56	47	45	49	115	116	66	60	60	132
Low pressure, KV	3	7	9	10	6,7	17,5	23,5	5,8	15	15	15	66
Frequency, cycles	50	50	50	50	50	50	50	50	16²/₃	16²/₃	16²/₃	16²/₃
Copper losses at full load, KW	108	44	51	90	31	38	35	40	145	66	48	90
Iron losses, KW	35	50	31	24	21	25	31	35	37	15	15	60
Short-circuit pressure, %	9,5	11,5	4,5	7,5	4,8	7,1	11,5	9,7	7,5	10	10	7,5
Weight with oil, tons	35	41	28	42	21	32	25	39	62	30	36	95
Cooling medium	Water	Water	Water	Water	Water	Air	Air	Air	Water	Water	Air	Air
Cooling surface, ft² (Cooling water, gals/min., respectively)	(25.3)	(16.5)	(14.3)	(19.8)	(8.8)	3760	3870	4310	(33)	(15.3)	4310	10760

III) Oerlikon oil circuit breakers.

Installation	Granada	Madrid	Catalana	Rupperswil		Siebnen
Year built	1922	1922	1917	1926	1926	1925
Working pressure, KV	55	90	130	66	132	150
Breaking capacity, KVA	80000	100000	400000	500000	500000	600000
Number of poles	3×1	3×1	3×1	2×1	2×1	3×1
Total weight, lbs.	3×1100	3×2420	3×21000	2×7700	2×22000	3×26400
Oil included in above, galls.	3×10.5	3×29	3×1450	2×400	2×1320	3×1400
Test pressure, KV	110	180	270	170	280	280
Max. height, feet	11	15	13.75	11	14.75	14.75



12000 KVA double induction regulator of the Neckar power station, at Aitbach.



Oil circuit breakers for 12 KV, 80 KV and 150 KV, respectively.

at the point of junction and where each system has to deal with a given portion of the wattless load. This problem has been solved by having recourse to double induction regulators and automatic power factor regulators. Such an equipment was installed, for instance, some time ago, at Broc, for connecting two systems operated at 58000 and 36000 volts, respectively, and for an exchange of power of 5000 KVA.

The erection of large power stations has led to the development of large transformers. With increasing voltages and capacities, special attention has to be paid to the insulating properties of the oil; in view of this, the contact surface between oil and air is reduced to a minimum so as to limit as far as possible the access of moisture to the oil. New methods have been evolved for removing the heat in a safe and economical way, preference being given to air cooling, as a rule. We are giving, in Table II, a few instances of large Oerlikon transformers.

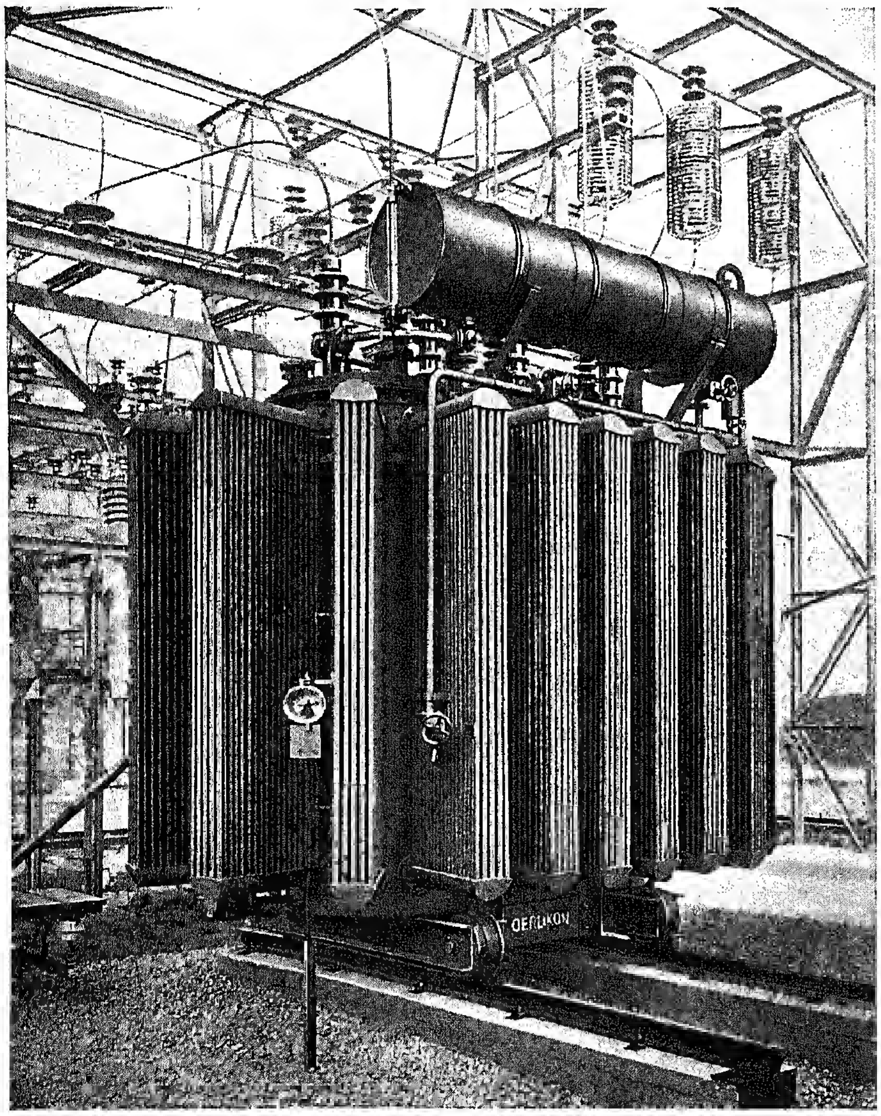
The interconnection of power stations results in a great increase in the short-circuit output in the high tension system. The circuit breakers for interrupting these large short-circuit currents and outputs are thus subjected to stresses which necessitate larger sizes of apparatus.

Table III contains some instances of large Oerlikon oil circuit breakers.

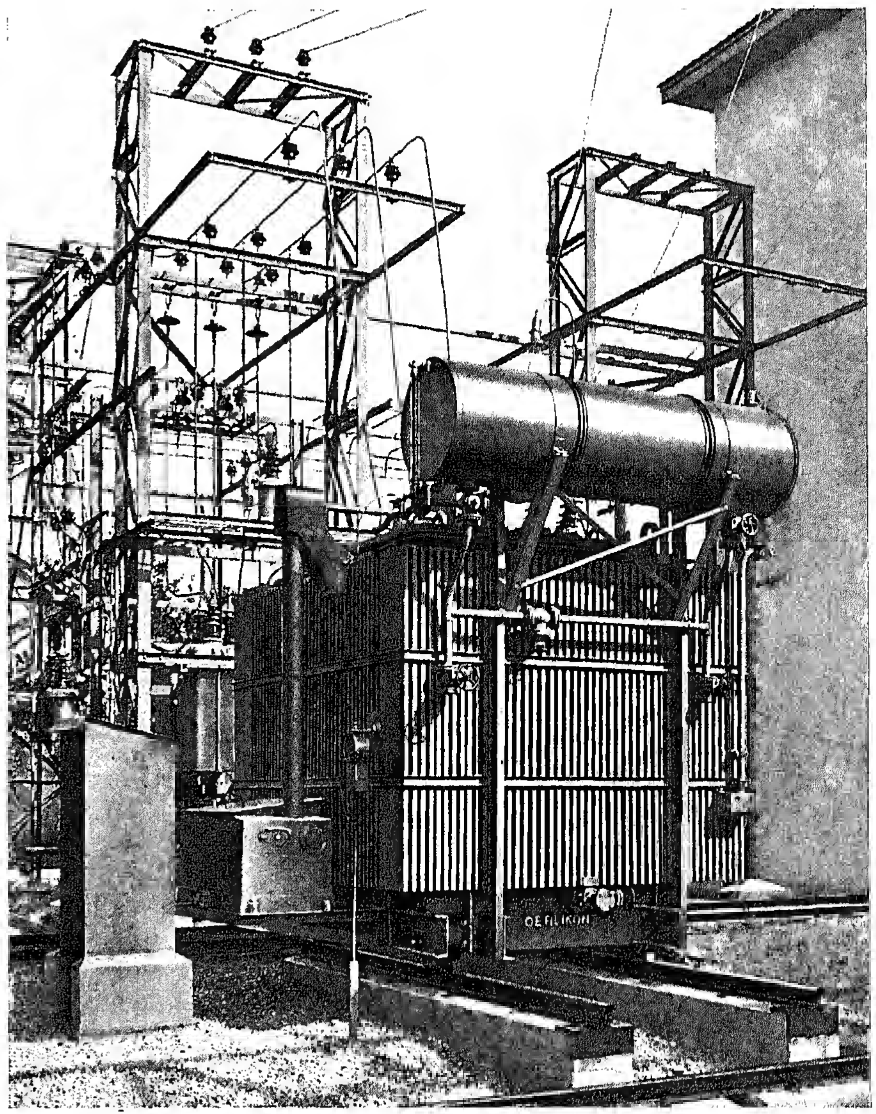
Notes and News Items.

The Berthoud outdoor substation of the Bernese Power Supply Company. The Bernese Power Supply Company have recently erected an outdoor substation in the neighbourhood of Berthoud. This installation serves to step down the pressure of the high tension system from 45000 volts to about 17000 volts, at which pressure the distribution takes place, and at the same time to keep the voltage between given limits by regulation. This substation ensures the power supply of the town of Berthoud as well as of the Emmen Valley.

A first transformer – induction regulator equipment has been installed provisionally; accomodation has, however, heen provided for two to three further equipments to be added at a later date. Both the transformer and the induction regulator have been supplied by the Oerlikon Company.



6000 KVA three-phase transformer, 49000/17000 volts, 50 cycles.



Induction regulator for 6000 KVA, 16000 volts ± 10 %.

The three-phase transformer, which is designed for use in the open, without protection, has a continuous rating of 6000 KVA; it is of the oil-immersed self-cooled type. The tank is provided with stacks of cooling tubes, in order to obtain the necessary cooling surface; each stack is connected above and below to flanges on the tank and comprises a number of tubes arranged in parallel. The core of the transformer is of standard construction; the winding consists of circular coils and is designed to withstand short-circuit stresses. The dimensions of the tank have been kept within such limits as to allow of the transport of the whole transformer by rail complete with oil.

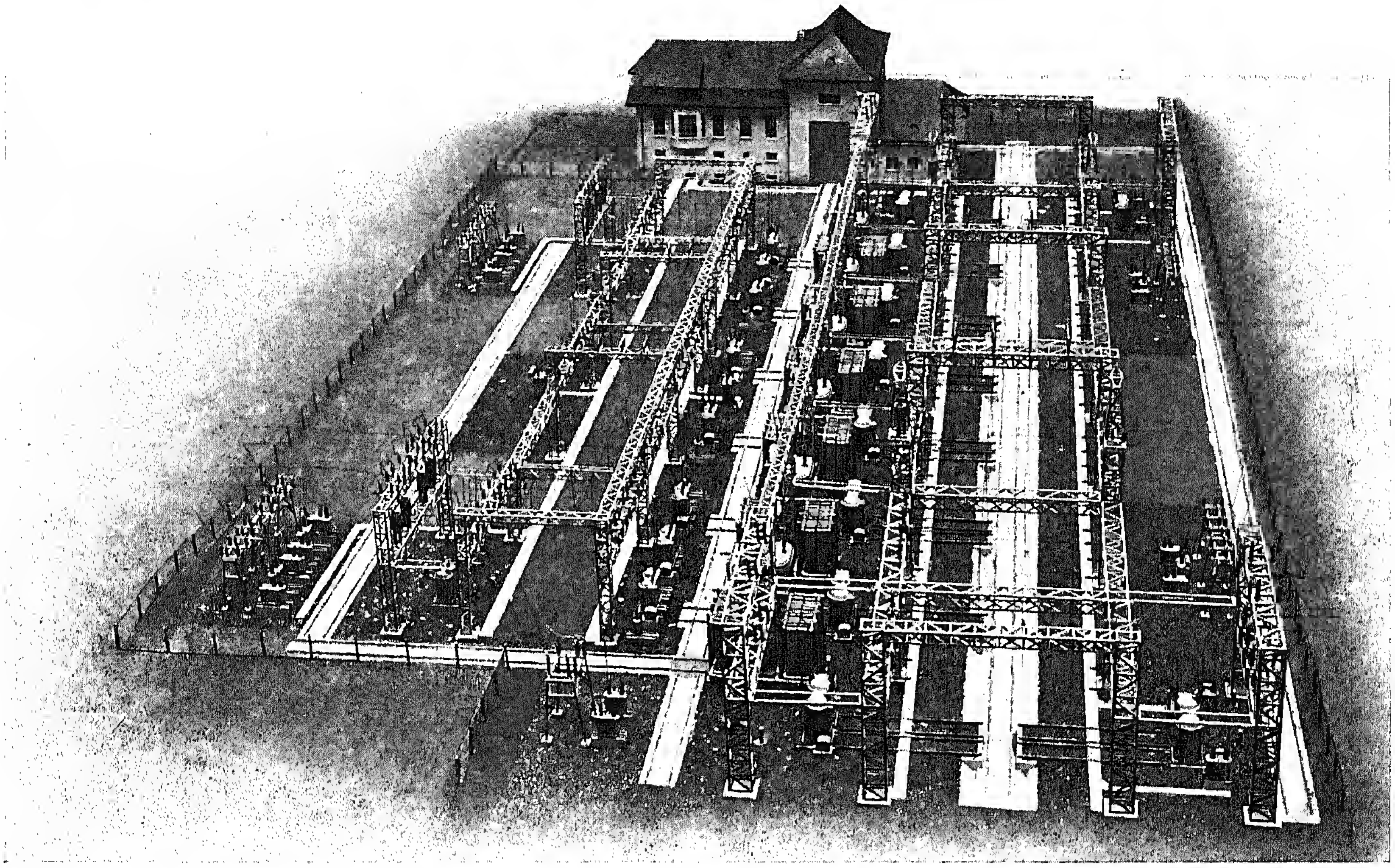
The transformer is directly connected to the induction regulator on the secondary side; the latter is also of the self-cooled type. The tank is, in this case, an ordinary corrugated iron tank. The induction regulator is dimensioned for an external capacity of 6000 KVA at pressures varying between 14400 and 17600 volts on the incoming side; on the outgoing side, the pressure is maintained at a constant value of 16000 volts. Rotor and stator are wound for the full pressure of system so that intermediate transformers can be dispensed with. The regulator is operated by a three-phase induction motor which is arranged in a separate casting on the side of regulator. The torque is transmitted from the motor to the worm gear of regulator, arranged over the rotor, by means of spur wheels and spindles. The regulator can also be operated by hand by means of a handle which can be fitted when the motor is switched off. An indicating device on the casing of operating gear shows the position of regulator at any time. The motor is controlled by a quick-acting regulator, in order to permit of the automatic regulation of pressure; this pressure regulator can either be set for constant pressure on the outgoing side or arranged with compounding for compensating the pressure drop in the outgoing line. All operating parts are specially designed and enclosed, to meet the special requirements of plant for use in the open.

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

BULLETIN OERLIKON

No. 68 — February 1927

Contents: On outdoor stations.



Model view of a substation for 6×9000 KVA, 132/66 kilovolts, 16⅔ cycles (in course of construction).

On outdoor stations.

The erection in the open air of electrical machines and switchgear without any roof covering was considered a hazardous enterprise in Europe for a long time, at least insofar as large plant was concerned. Today, however, these so-called outdoor stations have been introduced everywhere, and have exceeded all expectations, particularly regarding the reduction in initial costs; on the other hand, the fears entertained as to there being a reduction of security in service and duration of life have proved groundless.

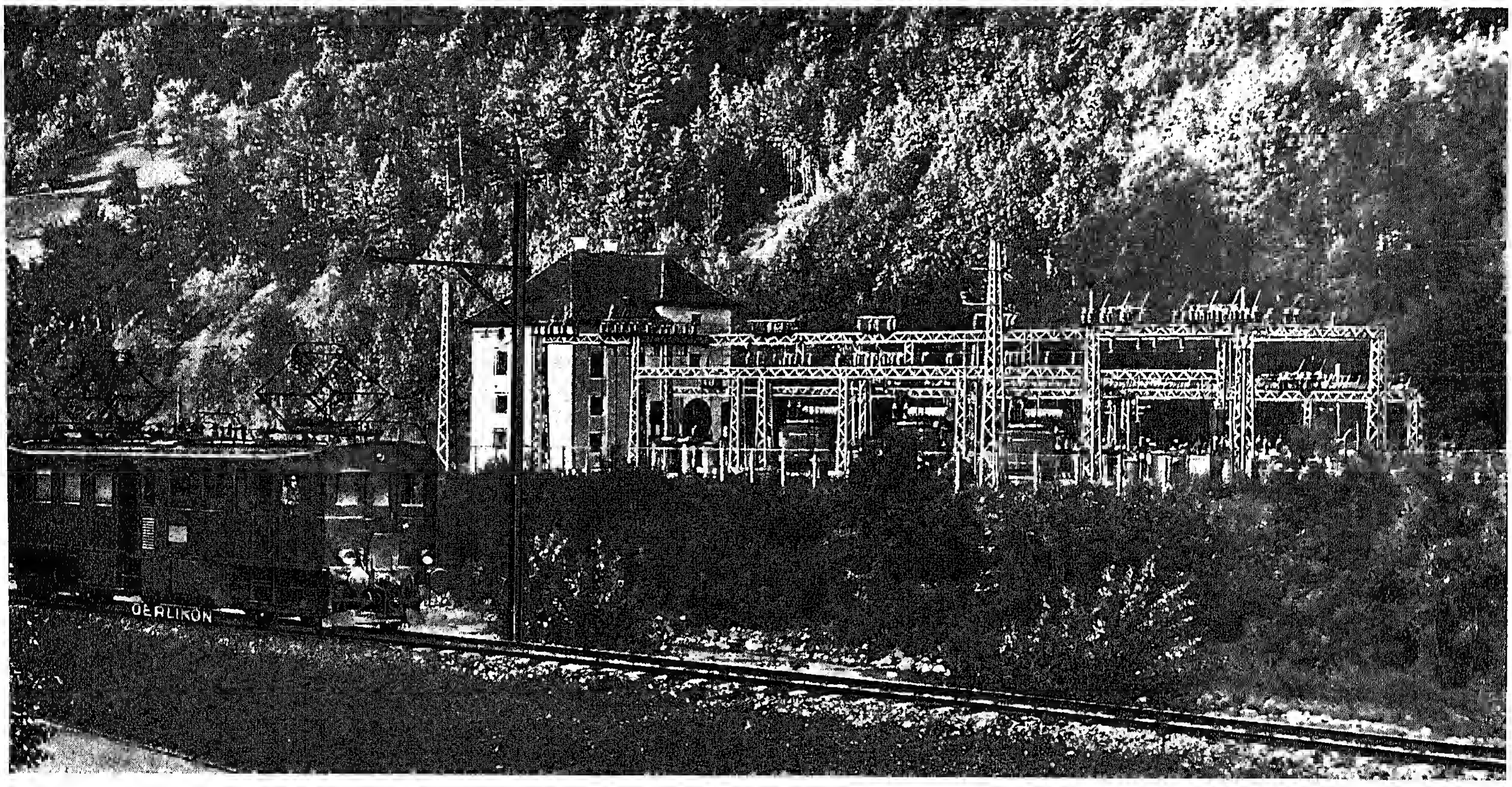
The requirements for special design suitable for outdoor erection were preliminarily restricted to transformers and switchgear. For several years, small stations of medium pressure with limited demand for energy have been built in Europe as outdoor stations.

The increased cost of building work has accelerated the development of outdoor stations for large outputs and high pressures, and at the present time it appears that, in Europe, the erection of transformer stations in the open will become standard, except in special cases where the surroundings demand an indoor installation.

At the beginning it was believed that outdoor distribution stations must, as in the case of indoor plant, be laid out with the utmost economy in space and also be arranged at several levels. As outdoor stations are preferably situated outside residential districts where the prices of the sites are still cheap, a saving in area is of small importance compared with the extra costs for maintenance when the arrangement is inaccessible, and not easy for supervision. The modern tendency is, therefore, to place transformers and switchgear side by side on the ground level or at an easily attainable height, accessible from every side and readily transportable. Only the conductors and disconnecting switches

are elevated on steel structures. In extreme cases, the conductors and disconnectors are also mounted at a low level and so-called "one-level stations" are erected. This construction is often decided upon in view of the advantages of periodical overhaul of the whole plant, which can be easily and quickly arranged in an adjacent covered workshop with convenient approach facilities. For this purpose, the machines and gear are fixed in such a manner that they can be easily removed from their position on a truck, and be replaced by spare gear, if such is necessary. The workshop has, therefore, to be arranged accordingly and it is advisable to have same fitted with an efficient oil cleaning plant. All parts of the installation have to be made suitable for the climatic conditions. the circuit breaker contacts after a certain number of switching operations is absolutely essential. Care should be taken to provide unobstructed outlets for any gases produced, in the rainproof switch tanks, through the working of this gear, but excessive oil throwing must be guarded against. All operating parts have to be protected against the formation of rust. This is easily possible, when ample provisions exist for sufficient temperature equalisation, and all bright parts are suitably greased.

The releases of the oil circuit breakers are preferably fed from an independent supply, which is arranged together with the control room and workshop in the service building. The question of excess pressure protection is debatable. Very good results have been obtained with suitable earthing of the neutral points and increased insulation in the substation, as compared with that of the transmission line.



Railway substation for 10000 KVA, 60000/15000 volts, $16^2/_3$ cycles.

Oil-immersed gear must be of such a design that a minimum of moisture enters the oil. Air spaces over the oil level have to be connected to the outer air in such a manner that a temperature equalisation is always effected. Only thus, can the formation of condensed water be avoided. Self-cooled transformers are preferable. Separately installed cooling systems permit satisfactory cooling of transformers up to largest outputs. Suitable and absolutely reliable plant must be used to accelerate artificially the oil circulation. The transformer tanks are generally filled completely with oil and fitted with expansion vessels, in which only a small oil surface comes into contact with the air. Furthermore, the air is cleaned and dried before entering the oil conservator. The temperatures in the transformer are electrically recorded in the control room, also any variation of the pressure in the tank and the oil circulation.

Oil circuit breakers must be so constructed that an exchange can be made in a minimum of time. An inspection of

All switchgear, even disconnecting switches, are preferably electrically controlled, whereby, several poles can be provided with common drive. Stranded copper or copper tubes are used for the conductors and given a solid coating of paint after erection. Bright parts of the switchgear are to be nickel-plated.

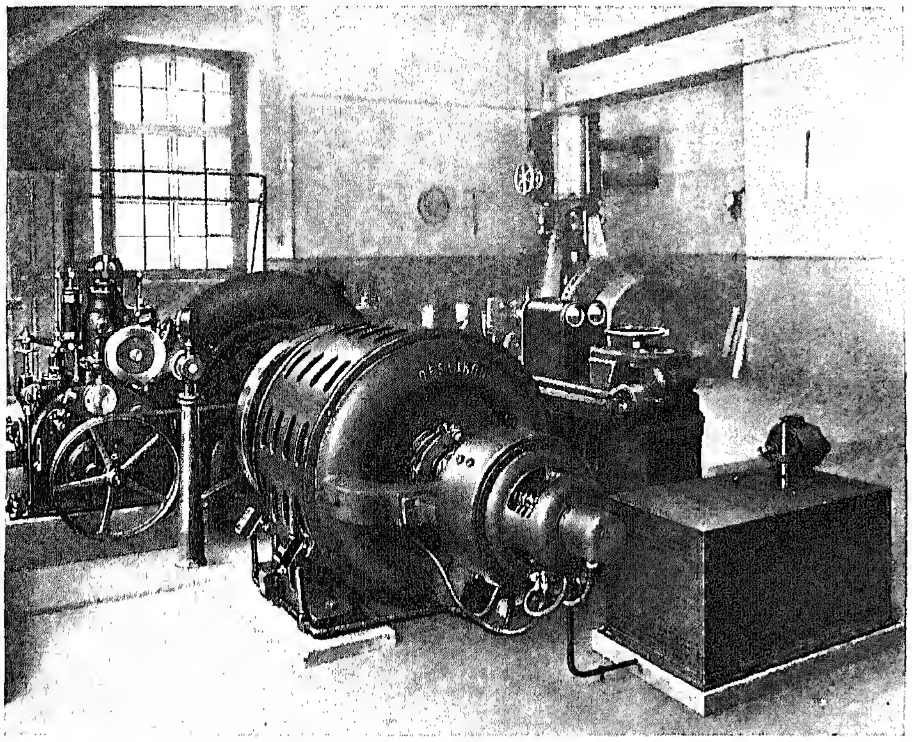
Petticoat type insulators made in one piece or assembled disc insulators with rigid fittings are used on this type of plant.

All switching operations should, whenever possible, be carried out from the control room. An automatic signalling device in the control room showing when the alterations in connections are effected, will be of good service. As a rule, easy supervision of the connections of the switch plant should be possible from the control room.

Notes and News Items.

Automatic power station with synchronous induction generators. In February 1925, the Services Industriels de la Ville du Locle placed an order with the Oerlikon Company for two hydro-electric sets, intended for the power station of Rançonnière. The problem was to arrange for the automatic operation of this station, both on the hydraulic and the electrical side. The equipment comprises two sets, one for 500 KVA and the other for 350 KVA; they are linked up by a common connecting line, with the busbars of the Locle distribution station, situated about 2.2 miles away. These busbars are either fed by the adjoining supply system and by the power station of Rançonnière together, or by the latter generating station alone. The conditions laid down were the following:—

1) Automatic starting up of sets from the Locle distribution station as well as from the Rançonnière power station itself.



500 KVA set with automatic starter.

2) Automatic synchronising of generators, with the busbars at Le Locle.
3) Automatic starting up of the 350 KVA set off the 500 KVA set and vice-versa, in the case where the Rançonnière power station should work alone without any current being derived from the adjoining supply system.
4) Remote control of the regulator of the water turbines of the two sets.
5) Remote control of the regulators of the generators with a view to adjusting the pressure from Le Locle when the Rançonnière power station is working alone, this being done either directly by push button control or indirectly by Thury regulator.
6) Automatic starting up and closing down of sets in the case of a fault in the pilot cables, in the case of racing of turbine, too great overload and excessive heating of bearing, core or ends of windings of generators.
7) In order to obtain great safety in operation all sensitive pieces of apparatus were, as far as possible, dispensed with.

The synchronising takes place without introduction of paralleling relays.

The conditions 1) and 7) led to the adoption of synchronous induction generators. These generators are switched direct

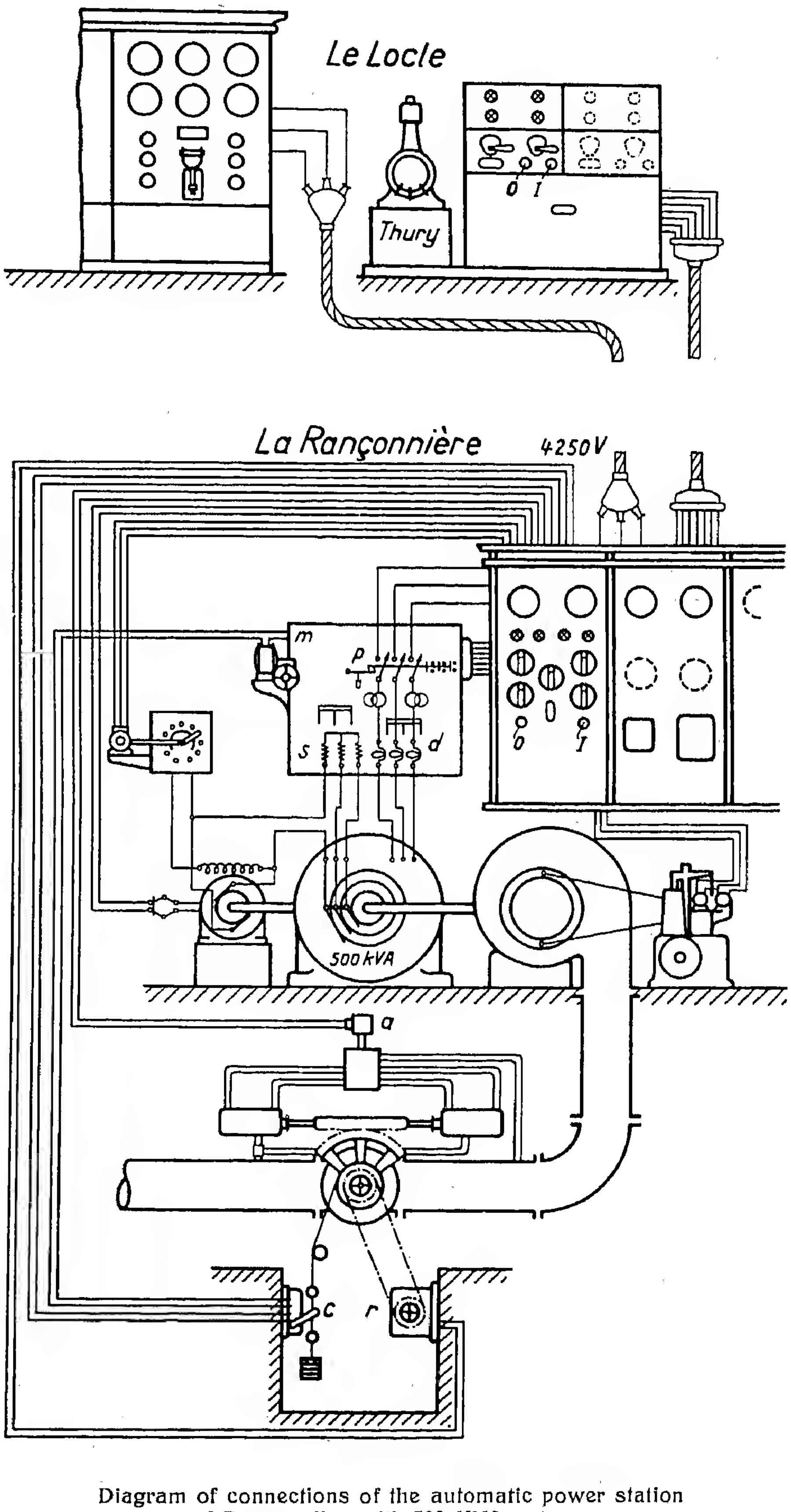


Diagram of connections of the automatic power station of Rançonnière with 500 KVA set.

on to the system, in the same way as induction motors, and synchronise automatically. In order to meet the third condition, it was necessary to damp the heavy rushes of current,

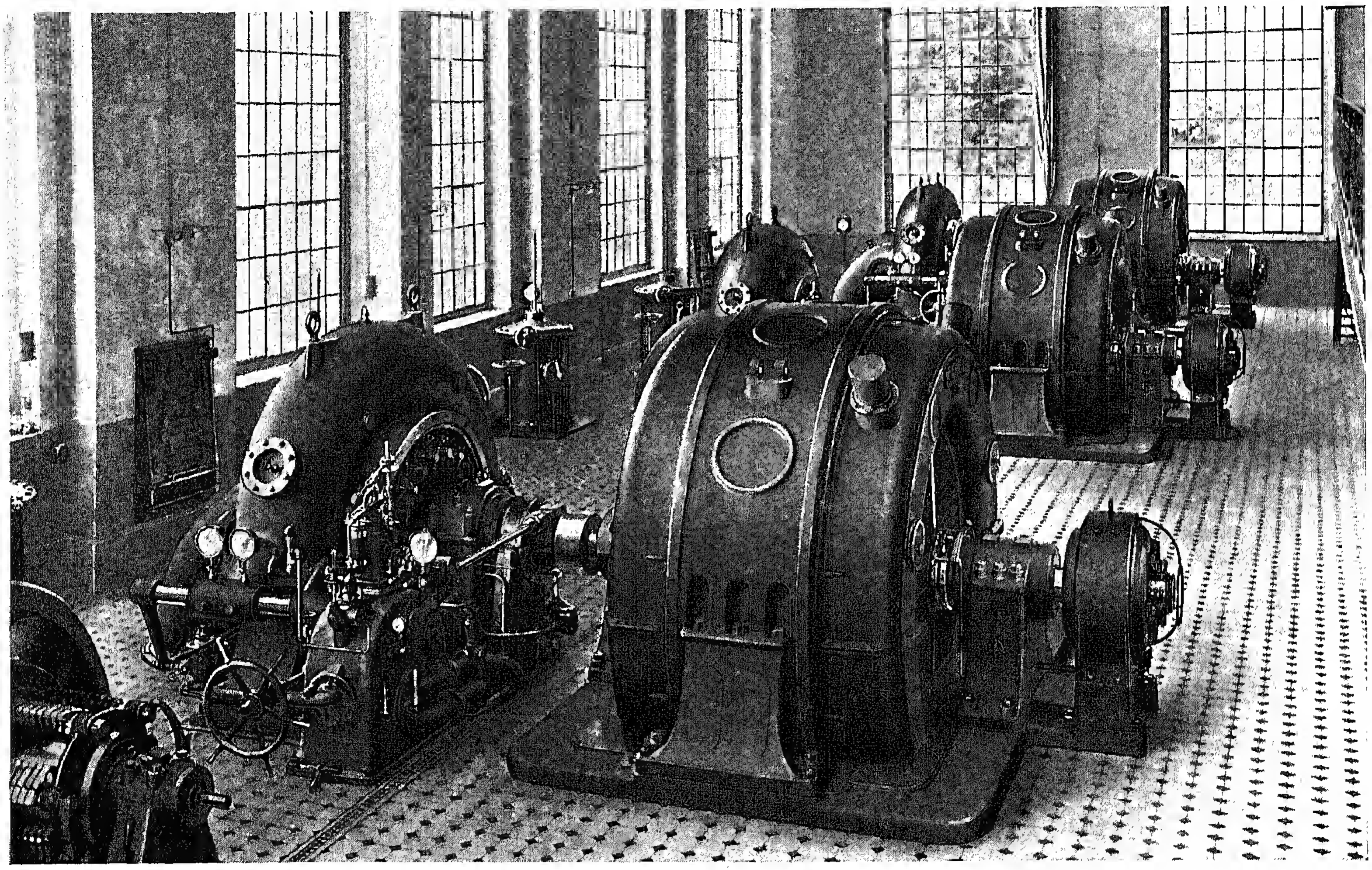
occuring when the plant comes into step. For this purpose, the starting gear is fitted with an auxiliary choking coil, which is only switched in for short periods.

The control circuits are fed with direct current and are so connected that, in the case of failure of the auxiliary supply, the sets are immediately closed down and brought to a standstill.

The diagram above shows the mode of operation of the automatic installation in question. To start one of the sets, the respective push button switch "I" is pressed (either in Le Locle or in La Rançonnière); this closes the circuit of the electro-magnet "a" in front of the rotary valve of the turbine. The armature of the magnet opens the valve of the hydraulic servo-motor, whereby the water acts on the piston, which operates the rack of the rotary valve. The valve opens gradually and operates, during its rotation, the change-over switch "c" of the starting gear "m", as well as the regulating resistance "r", which serves for the signalling of the valve position. At the end of the movement, the change-over switch "c" puts the servo-motor of "m" into service. Meanwhile, the water has entered the turbine, which attains gradually its normal speed. The servo-motor of the starting gear "m" causes the closing of the main circuit breaker "p" first, then short-circuits step by step the starting resistance "s" in the rotor circuit of the generator, and lastly the damper choking coil is also short-circuited. The generator is thus connected to the supply and synchronised. The shutting down and stopping of the set is effected by the pressing of the push button "0"; the main circuit breaker "p" opens and causes, at the same time, through the intermediary of an auxiliary switch, the interruption of the electro-magnet circuit of the rotary valve. This valve then shuts by itself.

Three-phase generators for the Spiez power station of the Bernese Power Supply Co. In order to meet the growing power demand in their distribution area, the Bernese Power Supply Company have been led not only to build new hydro-electric generating stations, but also to increase the output of their existing installations. Such a conversion was carried out in the Spiez power station where the five original 1000 KVA units where replaced by three new sets with generators supplied by the Oerlikon Company. The generators are each built for an output of 3400 KVA at 500 rpm., and wound for 16000/17600 volts, 50 cycles, three-phase. The machines are connected direct to the large distribution system of the Bernese Power Supply Company. They are provided with built-on exciter, the pressure regulation being ensured by acting on the excitation of exciter alone, by means of a quick-acting pressure regulator. The machines are each direct coupled to a 3500 HP. horizontal Francis turbine. As the pressure of the generators was rather high as compared with the output, the clients laid down very severe conditions as regards insulation of stator winding. All the coils were subjected to a test pressure of 40000 volts between the conductor itself and a tin foil sheath for one minute, before assembling the winding; furthermore insulation tests were carried out, once the winding was in position, with a pressure of 32000 volts between phases, and between phases and frame.

The rotor is made up of seamless rings of forged S. M. steel, shrunk on a powerful cast iron spider. The massive cast iron poles are secured to the rotor rim by means of the special Oerlikon method of fastening with claws inserted into round holes. The rotors were subjected to an overspeed test of 975 rpm., for one minute.

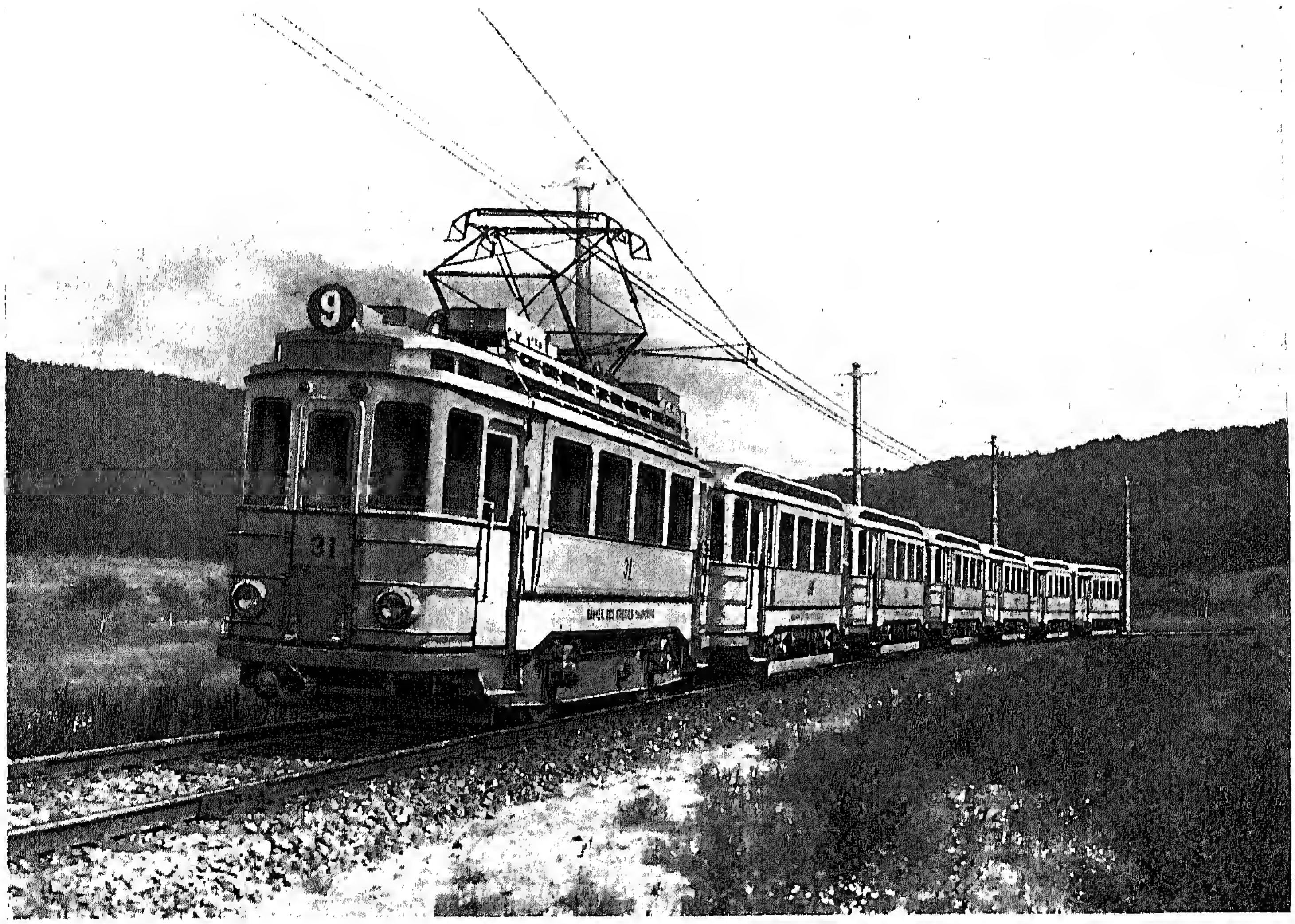


View of the machine room of the Spiez Power Station showing the three 3400 KVA generators.

BULLETIN OERLIKON

No. 69 — March 1927

Contents: The Saarlouis-Kreuzwald line.



100-ton train of the Saarlouis-Kreuzwald line.

The Saarlouis-Kreuzwald Line.

This line is mainly intended for conveying the workmen living in the Saarlouis district to and from the La Houve Mines; it is a standard gauge single-track line, and has a maximum gradient of 1 in 33.3. The length of line is about 9 miles, 14 intermediate stations being provided.

The workmen's trains consist of one motor coach and six trailer coaches, representing a total load of 100 tons. For the other trains, the number of passenger coaches and goods trucks coupled to the motor coach depends upon the requirements. In order to be able to deal with the heavy trains, each motor coach is fitted with two D. C. series motors, each developing an output at wheel rim of 100 HP at 17 m. p. h., the pressure at terminals being 750 volts. The maximum speed is 31 m. p. h. The motor bearings and the axle bearings are of the ball bearing type; the motors are designed for starting up against twice normal torque. The trains are fitted with continuous air brake and light signals.

The results obtained during operation have been extremely satisfactory, specially in the case of the heavy workmen's trains.

H. T. Electrode Steam Generators for Pressures of 3000 to 8000 volts.

It is now the usual practice, when raising steam by electricity, to resort to electrode steam generators connected direct to the high tension supply. In the case of pressures of 3000 to 8000 volts, three-phase, the electrode boilers can be designed for capacities from about 300 KW onwards and can be built for outputs up to 5000 KW and more, as the pressure adopted increases.

These electrode steam generators are suited, for instance,

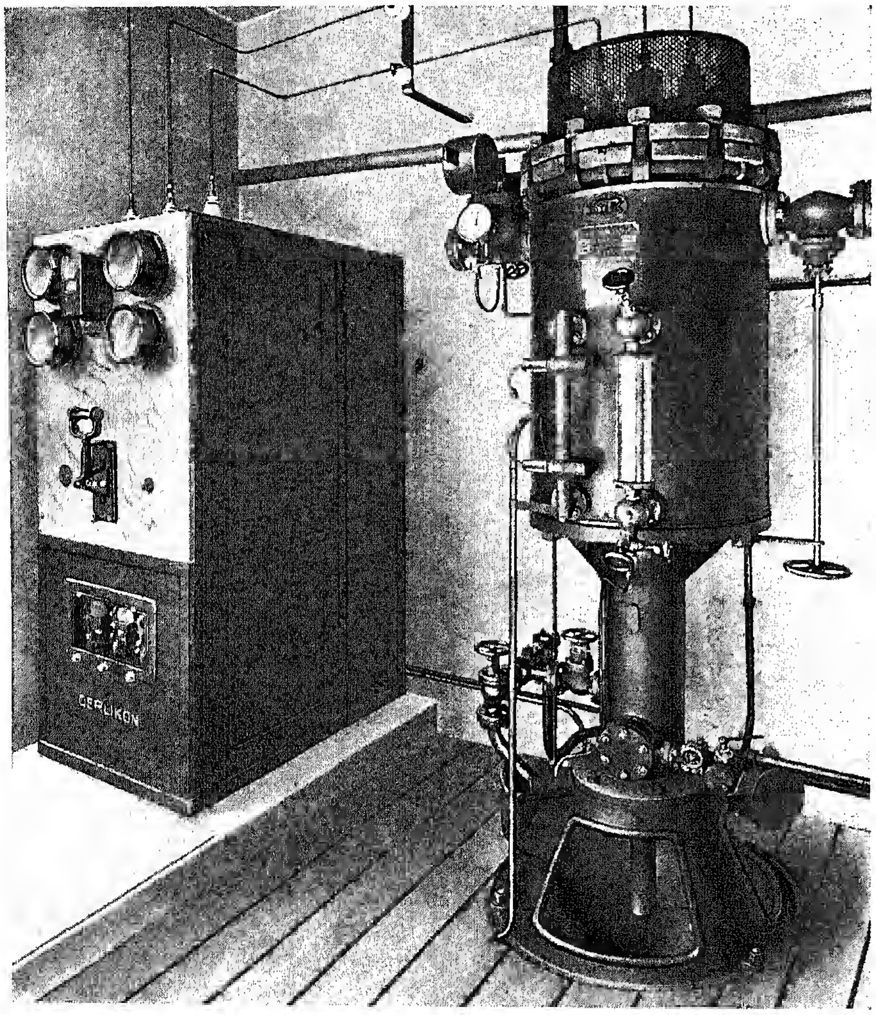


Fig. 1.

for utilising surplus energy, and more especially night current, such as can be obtained at low rates from hydro-electric power stations; but, even in the case of steam power stations, the sale of night current may be of advantage to an electric undertaking, when one or more boilers have to be kept under pressure for standby purposes, and are thus only partially utilised.

The illustration on this page represents an equipment which was installed by the Electricity Works of Aarau, Switzerland, at the Lonstroff Rubber Works in that town. The capacity of the plant is 600 KW at 5200 volts, 50 cycles. The steam produced in the electrode boiler during the day is led either directly to the presses and cookers, or into the old flue boilers which are now used for standby purposes. The flue boilers themselves have not been fired a single time since the installation of the electrode boiler in 1920 — a fact that testifies to the reliability of this method of raising steam by means of electrode steam generators; they are now used solely for equalising the load, as the steam consumption of the Works is very fluctuating. Should there, however, be a shortage of water at the power station, the flue boilers can be fired at any time.

The Oerlikon Company, in conjunction with Messrs. Escher Wyss & Co. of Zurich, have installed a large number of H.T. steam generators not only in Switzerland, but also in many other European and Overseas countries, which haven given entire satisfaction. A large 1200 KW equipment for 6000 volts has been in service for some time at one of the hospitals of the City of Basle (Fig. 2). The two existing flue boilers there are now used for standby purposes only; there is, on the other hand, a separate steam accumulator with a storage capacity of 2500 KW-hours, which can feed the different parts of the hospital when the electrode boiler is not working. This accumulator is loaded up to a pressure of 170 lbs. per sq. in. and supplies the steam through a reduction valve at any desired pressure below that value. The hospital requires steam for the kitchen as well as for the laundry. In addition to this, hot water is also needed; this water is heated in a separate counter-flow apparatus, by means of the steam generated in the electrode boiler, and stored in large tanks. The electrode boiler thus fulfils here the double function of supplying both steam and hot water.

Two similar electrode boilers, each for 1000 KW, 6000 volts, have been recently ordered for an installation in England. Though the current is derived, in this case, from a steam power station, the operation of electrode boiler is economical under present conditions; this is due to the fact that the current is obtainable, here too, at a reduced rate during the night, while the low price of boiler, the small space needed and the limited attendance required, are very important advantages for the installation in question. On the other hand, the fact that no coal storage room is necessary, that chimneys can be dispensed with, and that smoke is eliminated, is also a matter of no little importance in a town.

The following are a few particulars regarding the design of the H.T. electrode steam generators themselves:—

The output can be easily regulated by varying the level of water. The maximum output corresponds to the highest level of water, so that the surface of electrode in contact with the water and the volume of water have then the greatest value. The boiler has no storage capacity, this being a favourable feature with respect to rapid heating up. The H.T. electrode boiler is, in outward appearance, similar to a L. T. electrode boiler, but differs from it in certain details of construction. The electrodes are separated by insulating bodies arranged in an iron frame fitted inside the boiler; these insulating bodies are of very simple design, unlike those in other makes of boilers, which are in the form of tubes easy to break or assume very complicated shapes, so that forced water circulation is required. The bushings of the electrodes in

the cover of boiler are somewhat longer than those of L.T. boilers, but consist also of three simple sleeve-shaped parts; there are no stuffing boxes, the joints being rendered perfectly tight automatically, as a result of the pressure inside the boiler. The equipment works as a star-connected plant, with the boiler itself acting as neutral point.

The wear of the electrodes, as well as of the insulating parts is very small. The electrodes, which are secured to the cover, can be removed by raising the latter; the insulating bodies between the electrodes can also be withdrawn together with the frame carrying them. Tests on an H.T. boiler for 1200 KW and 6400 volts have shown that the efficiency of this plant can reach 98 %. For the protection of plant, provision is made for a triple-pole oil circuit breaker mounted on the control panel and fitted with three overload relays. As a further safeguard, two water contacts can be provided on the boiler; the upper one switches off the feed pump if the water in the boiler reaches a too high level, while the lower one causes the main circuit breaker to open when the level of water drops too low, and thus prevents the interruption of current from taking place in the boiler between the electrodes. The operation of plant is thus absolutely safe, while the maintenance is very simple.

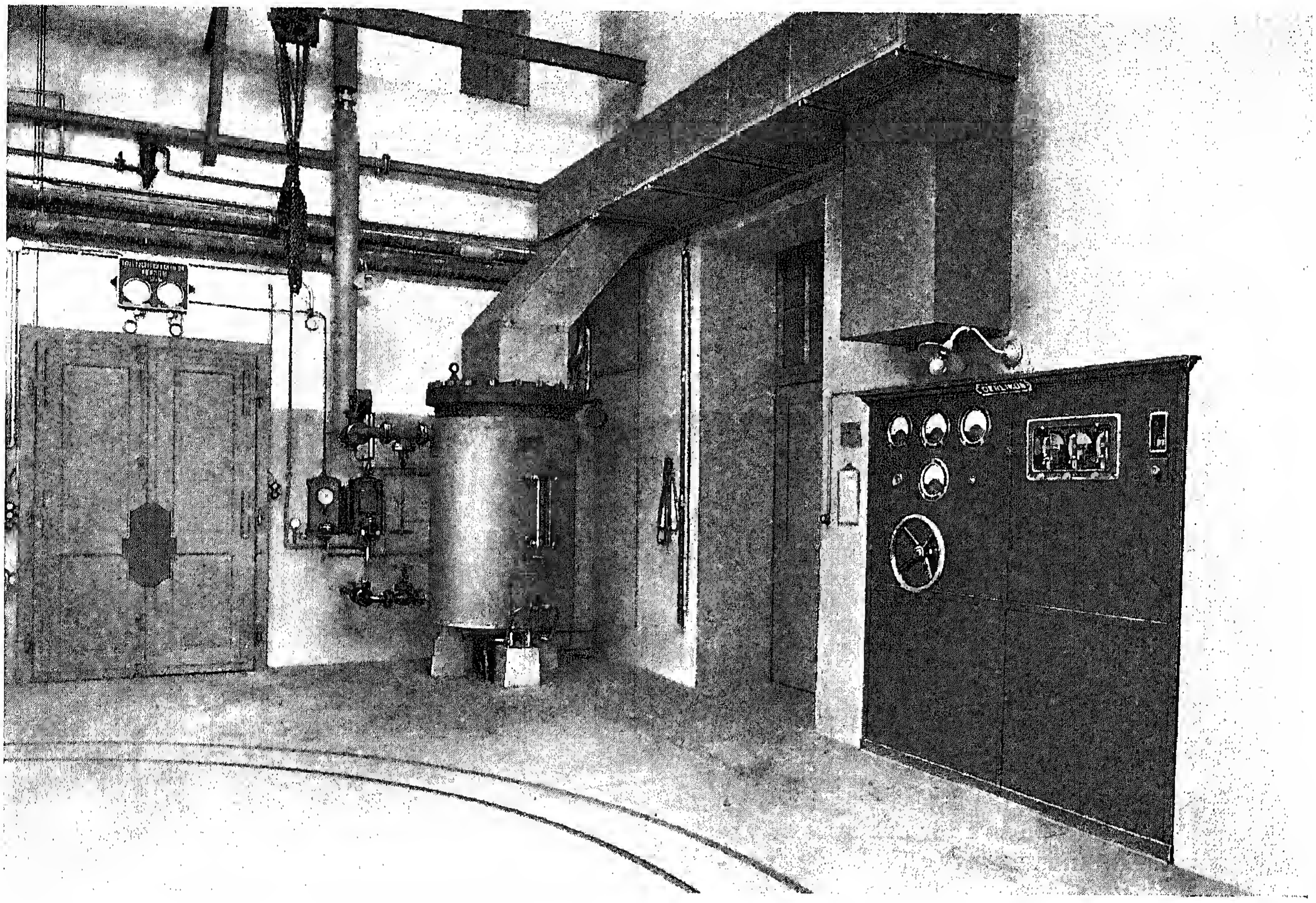


Fig. 2.

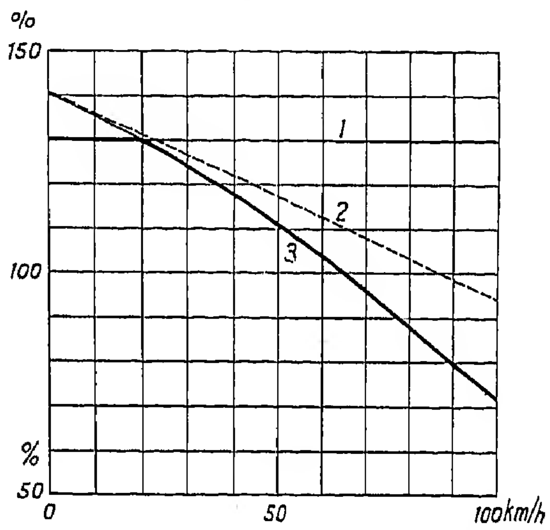
Notes and News Items.

Improvements in the design of single-phase traction motors. As a result of exhaustive studies and systematic tests, the knowledge regarding phenomena in single-phase motors, and more especially in respect of starting, commutation and heating, has been greatly extended and many points definitely cleared up. This has meant a considerable increase in the data available for the calculation and design of this type of motor and it has thus been possible to improve this plant in several respects. The following are some of the special features of the new design.

The coils of interpoles and main poles are completely wound and insulated by a special method, before insertion in the iron core. As regards the distributed compensating winding, it is retained in the case of all motors, as, apart from permitting of a good utilisation of motor, it fulfils the necessary function of rendering the motor non-sensitive to current rushes and pressure fluctuations. This winding consists of individual bars, which are also completely insulated with pressed-on mica, before insertion in the core, except at the places where they are soldered. Owing to the good sub-division of stator, and ventilation arrangements, the cooling is very effective and all local heating is avoided. On the other hand, the excellent mechanical design and insulation render the plant as far as possible immune against breakdowns. It may be mentioned that there has not been a single instance of a breakdown in the case of the many windings of this type in service. The stator windings made according to the new process only heat to a limited extent, even under very severe conditions. Measurements made on the new motors for freight locomotives, as well as on those for individual drive on express locomotives — both for the Swiss Federal Railways — have

shown that the temperature reached, at no point of the stator, more than 60 % of the heating limit, in the case of one-hour operation, and 50 % on continuous service.

The advantages of this design of motor with very amply designed stator can be clearly seen from the illustration. The tractive effort permissible from the point of view of heating of stator, rotor and commutator, is shown there in relation to the speed. The continuous tractive effort at 65 km/h. (40 m. p. h.) is taken there as 100 %. The heating of stator is practically independent of the speed; the permissible value of current decreases, however, with increasing speed in the rotor, owing to the losses being dependent upon the rotor frequency and, in the commutator, owing to the variable friction effect. The tractive effort is limited by the stator up to a speed of about 20 km/h (12.5 m.p.h.) and afterwards by the rotor. This type of motor can thus deal with heavy train loads at low speeds (goods trains) or can be subjected to severe starting conditions immediately after continuous operation. The rotor design of the motors for express locomotives further embodies a new arrangement of winding. The ends of the lower rotor bars projecting beyond the core are not bent over, on the commutator side. The rotor bars are wider in the part corresponding to the upper layer, than in that corresponding to the lower layer. The bars of the upper layer are thicker, but not as high as those of the lower one, so that the eddy current losses are reduced. The bars of the lower layer are, in the case of each individual slot, completely insulated before insertion, and each constitutes a coil unit; these units are inserted axially in the upper widened portion of the slot and then brought down radially to the bottom of slot. The advantages of the semi-closed and of the open slot are thus combined, in the case of the lower layer. The air space between the straight ends of bars affords very good cooling facilities. In the recent designs of motors, the equipotential connections form, together with a special supporting ring, a disc-shaped body which can be screwed to the completely wound armature and screwed off when dismantling the latter. Special attention is paid to the manufacture of the commutator.



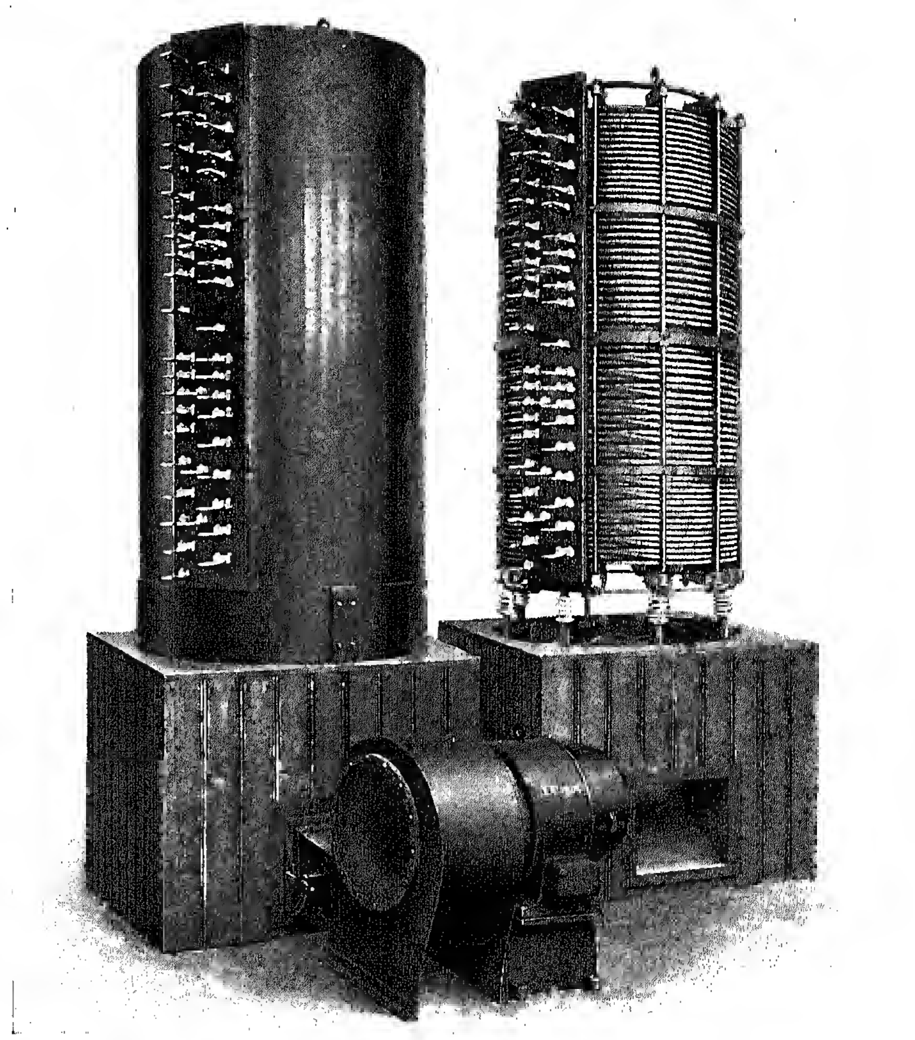
Tractive effort permissible with regard to heating of the different parts.

1 Stator windings
2 Commutator
3 Rotor winding

The foregoing remarks show that these single-phase series motors with commutating field displaced in phase, according to the method of Dr. Behn-Eschenburg, although unaltered in their essential features, have been improved very considerably.

Loading reactances for large generators. In order to be able to test even the largest units at full load at the Works, the Oerlikon Company have recently built reactance coils which make it possible to load inductively (at cos $\varphi = 0$) single- and three-phase generators up to very high outputs. In such a case, the motors driving the generators in question need only to be sufficiently large to cover the full load losses of the latter (in certain cases excluding excitation) and those of the reactance coils. Two such coils are represented here. When a three-phase load is required, three units are installed.

The windings of coils are made of stranded copper cable, so that the eddy current losses are small. These coils can be used for the most varied pressures and currents as they are made up of different sections with numerous tappings. The space round the winding is limited inwardly and outwardly by thick insulating cylinders of resinous paper; the winding in this annular chamber is cooled by a powerful draught of air, which is produced by a blower fitted to the equipment. For three-phase loads and 50 cycles, the coils can be used, for



the following conditions, for instance:—
at 2200 volts . . . for 350 to 11000 KVA in about forty steps.
at 6600 volts . . . for 3000 to 25000 KVA in twenty-four steps.
at 11000 volts . . . for 8500 to 45000 KVA in twelve steps.

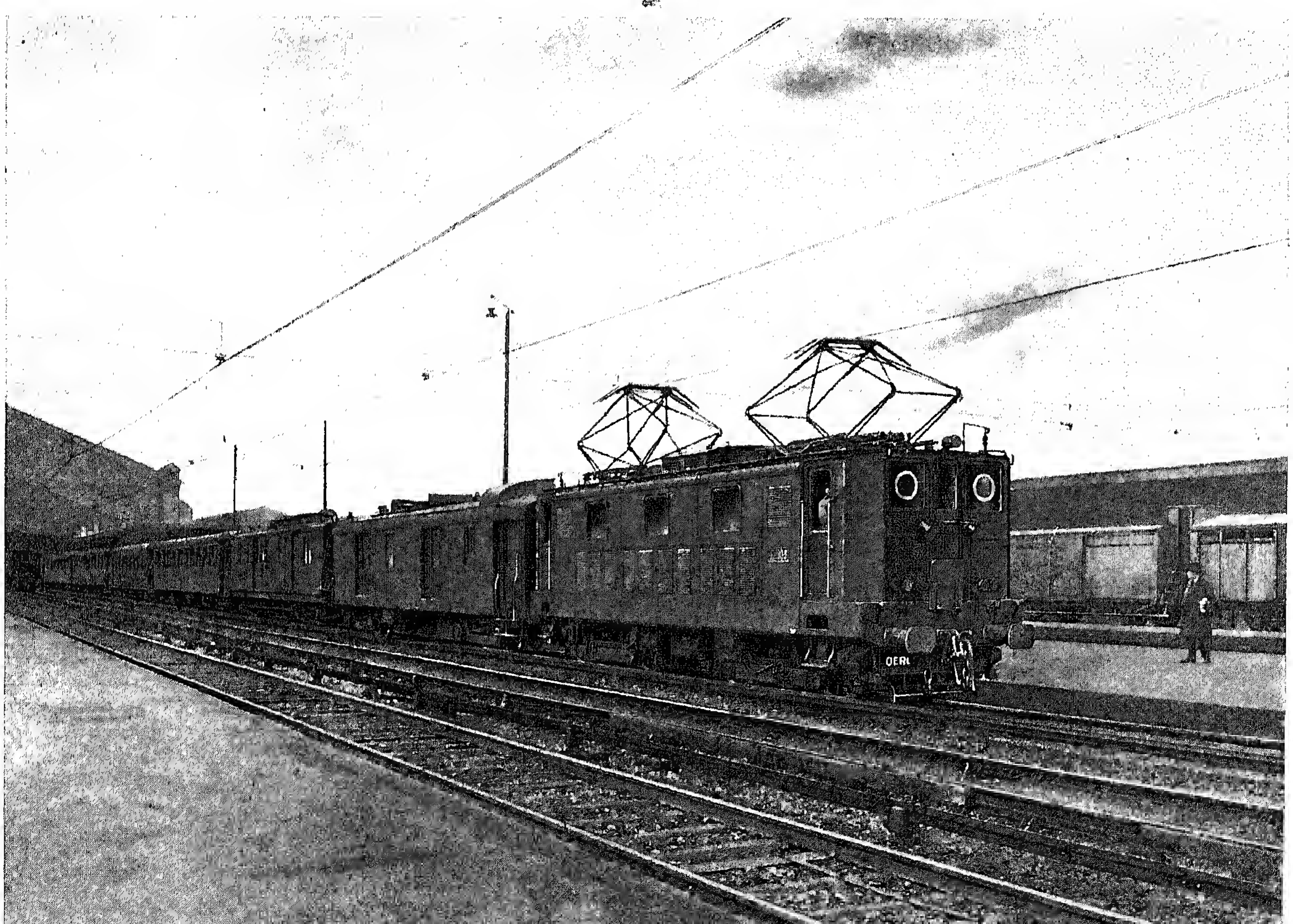
At other pressures, a corresponding range of loading is obtainable. In the case of other frequencies than 50 cycles, the capacity varies in the same ratio as the frequency. The use of these choking coils for loading purposes permits, in the first place, of an accurate study of the heating at full load, such conditions being only attainable incompletely during ordinary service and with much loss of time. On the other hand, with this method, it is possible to determine the actual efficiency much more accurately than when the latter is based on the light load and short-circuit losses; this is due to the fact that, with large units, the eddy current losses which occur under short-circuit conditions are much smaller than when the plant is working at normal pressure.

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

BULLETIN OERLIKON

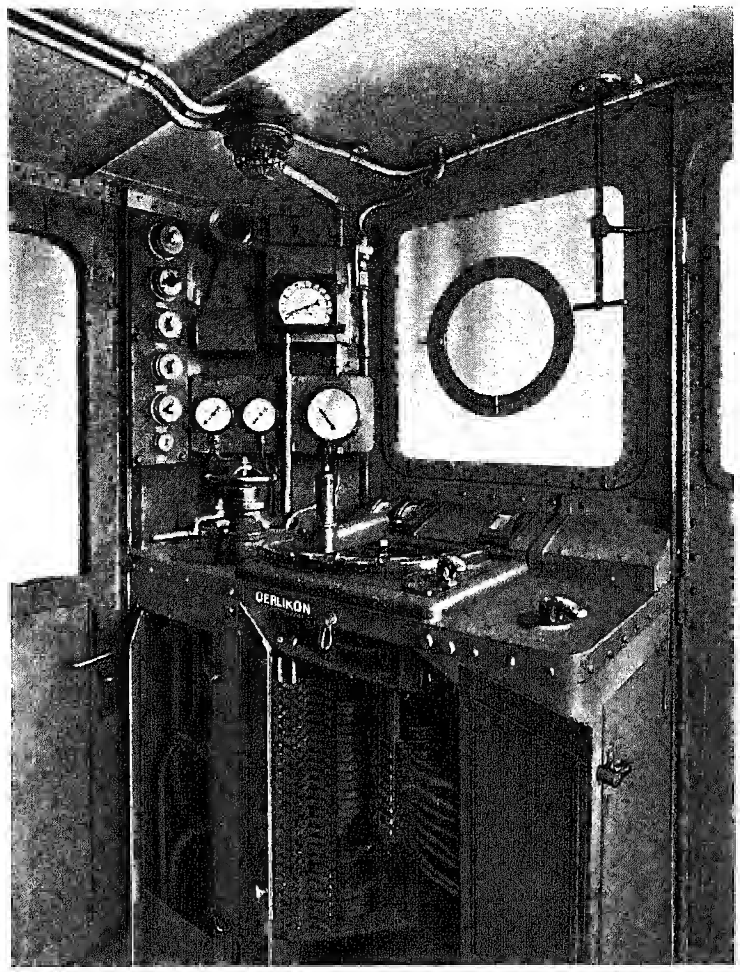
No. 70/71 — April/May 1927

The Locomotives EBB101 to 180 of the Paris-Orléans Railway and the Traffic They Have to Deal With.

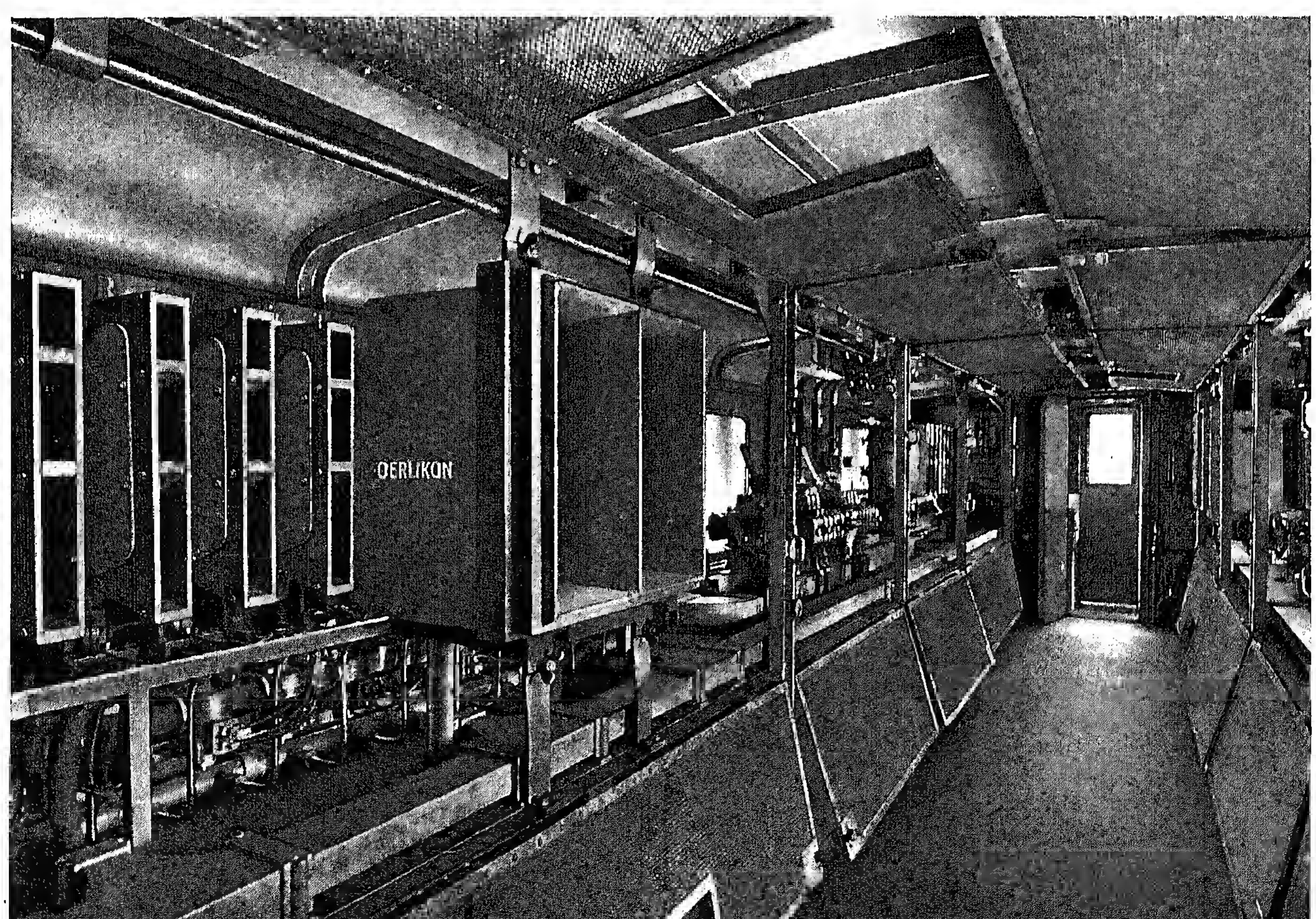


Express train at the Paris-Austerlitz station.

Driver's cab.



Master controller open for inspection.



Central compartment. Screen lifted to permit of the inspection of H. T. gear.

The Locomotives EBB101 to 180 of the Paris-Orléans Railway and the Traffic They Have to Deal With.

In Oerlikon Bulletin No. 20, of February 1923, we gave a general description of the mechanical part and the electrical equipment of these locomotives; as stated at the time, it was proposed to revert to the matter in a subsequent issue, and to complete such particulars as were given by actual data obtained during normal service, as well as during preliminary tests, so as to show the kind of traffic the locomotives were capable of dealing with.

The main particulars of the locomotives EBB 101 to 180 are as follows:—

Tractive effort at wheel rim in lbs.	Speed in mph.	Output at wheel rim in HP		
23100	28.5	1800	One-hour rating	at 1350 volts with forced ventilation
18400	30	1500	Continuous rating	

Maximum tractive effort at start	47500 lbs.
Gear ratio	1:3.47
Maximum speed	62 mph.
Length over buffers	40 ft. 8 in.
Distance between centre pins	19 ft. 4 in.
Total wheel base	28 ft. 6 in.
Diameter of wheels (with new tyres)	4 ft. 5.1 in.
Total weight of locomotive	75.6 tons.
Weight of electrical equipment (including gears, pinions and gear case)	31.7 tons
Weight of mechanical part	43.8 „
Weight of suspended parts	54.4 „
Weight of body alone	35.7 „
Weight of complete bogie	19.9 „
Weight of sprung part of bogie	9.4 „
Weight of non-sprung part of bogie	10.5 „

The first locomotive was supplied to the Paris-Orleans Railway on the 1st. May 1923 and, at the present time, about 40, i. e. half the total number ordered by the Paris-Orleans Railway in July 1922 from the Oerlikon-Batignolles Companies, are in use on the electrified system of that railway, where they are used, in particular, to ensure the service on the Paris-Brétigny-Dourdan and the Paris-Brétigny-Etampes-Orleans-Vierzon lines; these locomotives serve to haul goods and produce trains and ordinary passenger trains and are also utilised, to a considerable extent, to deal with express service. In the latter case, the locomotives EBB101 to 180 actually take the place of fast electric locomotives, as the Paris-Orleans Railway have only a few such locomotives primarily intended for trial purposes.

We shall briefly describe the different classes of traffic in question.

a) Freight trains.

Average trailing load	800 to 1200 tons.
Nominal speed	18.5 to 25 mph.
Highest average speed	28 to 31 mph.

b) Produce trains.

Average trailing load	350 to 500 tons.
Nominal speed	40.5 mph.
Highest average speed	56 mph.

c) Ordinary passenger trains.

Average trailing load	250 to 350 tons.
Nominal speed	40.5 mph.
Highest average speed	56 mph.

d) Express trains.

Average trailing load	300 to 500 tons.
Nominal speed	46.5 mph.
Highest average speed	56 mph.

We would point out here that the nominal speed is a fictitious speed which serves to characterise the class of train service; it differs more or less from the actual speed of train laid down in the corresponding time table, according to the profile of the different sections of the line over which the train travels.

If we examine the different classes of traffic to be dealt with by these locomotives, we see at once that the latter must have, on the one hand, a very high torque to permit of the starting up and hauling of the heaviest trains. On the other hand, their output must be sufficient to enable them to make, without difficulty, long runs with express trains, as on the Paris-Vierzon line, which has a length of over 125 miles, involving a weekly mileage of locomotive of 370 to more than 440 mile-trains per day, according to the schedule of operation.

The trials carried out in this connection by the Paris-Orleans Company have given quite conclusive results. A train consisting of 58 empty goods trucks was used for these tests, the train weight being 578 tons (excluding the weight of locomotive). During the trials, the current taken by each motor for all modes of grouping was kept at 250 amps, without resorting to the intermediate shunting notches. These

results are shown in Figs. 4 and 5, where two starting curves are reproduced; the latter were obtained by means of a recording ammeter. These curves indicate the variations in current and, consequently, in tractive effort between the different starting notches, the average pressure being 1230 to 1250 volts.

An analysis of these curves shows, as could be expected, that the greatest variation in current and, consequently in tractive effort, takes place for parallel grouping with 100 % field. This variation in tractive effort is, however, quite normal within these limits; it amounts, in fact, only to 2090 lbs. in all, with this mode of grouping, the corresponding variation in current being about 22 amps per motor. The maximum variation in tractive effort recorded was about 3300 lbs. in all, the corresponding variation in current being 35 amps. per motor. It is also interesting to note the starting times which amounted to 4 min. 20 secs up to a final speed of 26 mph., when starting on a gradient of 1 in 125, and to 3 min. up to a final speed of 23.3 mph., when starting on a gradient of 1 in 143.

The following table further gives a few running data obtained during these tests (trailing load = 578 tons).

Mode of grouping	Speed mph.	Current per motor amps.	Tractive effort
Series, 100 % field, on level	12.4	50	2860 lbs.
Series, 100 % field, on 1 in 166 gradient	7.45	160	11450 „
Series, 100 % field, on 1 in 125 gradient	6.82	190	13850 „
Series-parallel, 100 % field, on level	22.3	65	3630 „
Series-parallel, 100 % field, on 1 in 166 gradient	15.5	175	12750 „
Series-parallel, 100 % field, on 1 in 125 gradient	14.85	205	15400 „

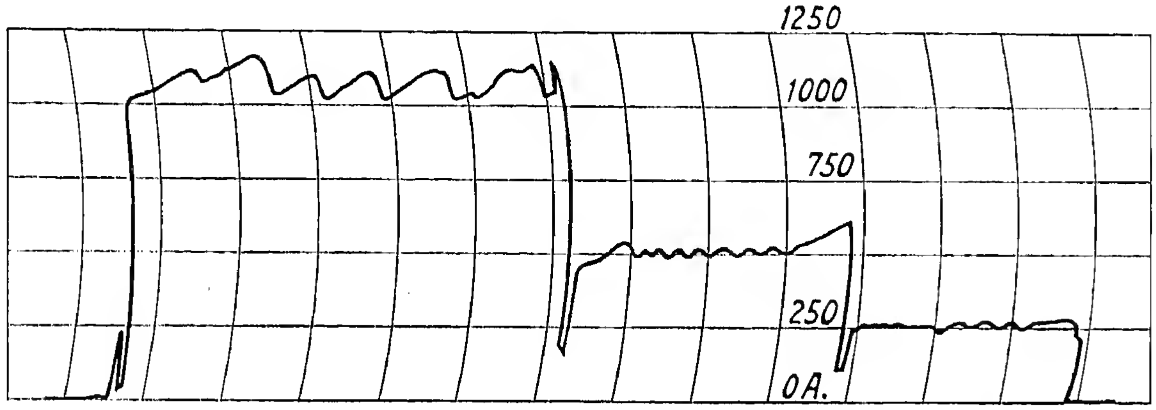


Fig. 4. Starting test with 250 amps on gradient of 1 in 143.
Strip taken with recording ammeter. 1 division = 14 2/5 secs.
Trailing weight 578 tons. Duration 3 minutes. Distance .62 mile.
Power consumption 41 kw-hours. Average working pressure 1230 volts. Speed at the end of test 23.3 mph.

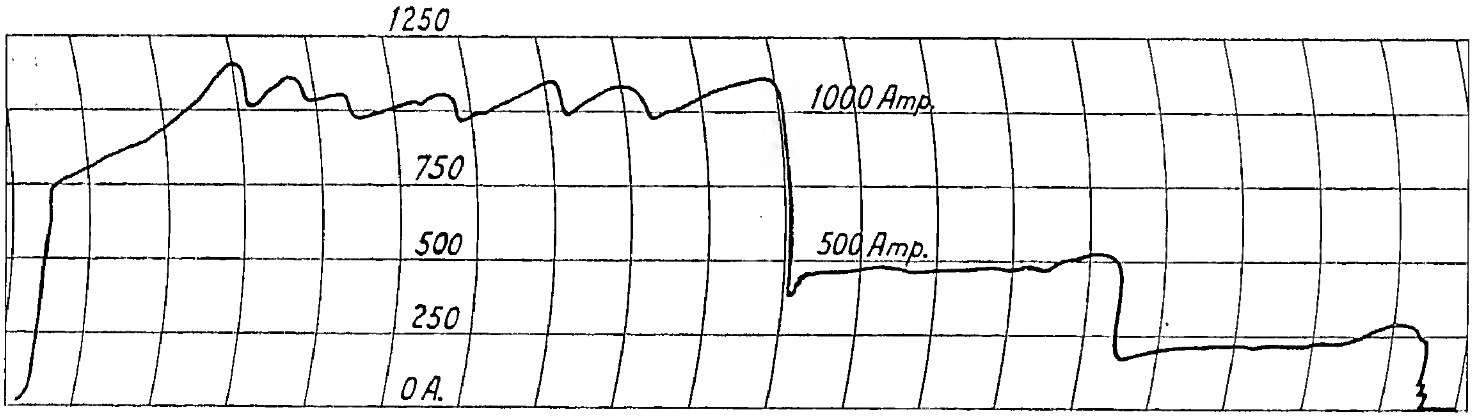


Fig. 5. Starting test with 250 amps on gradient of 1 in 125.
Strip taken with recording ammeter. 1 division = 14 2/5 secs.
Trailing weight 578 tons. Duration 4 min 20 sec. Distance 1.025 mile.
Power consumption 70 kw-hours. Average working pressure 1250 volts. Speed at the end of test 26 mph.

The acceleration of these locomotives must be sufficiently high to permit of rapid starting up when hauling express trains as well as when dealing with ordinary passenger trains; in the latter case, in particular, it is of the utmost importance from the point of view of power consumption and of punctual running to start up very quickly, owing to the numerous stops. The following are the values obtained for the acceleration at start, with a train of 290 tons:—

.448 mph./sec. on gradients of 1 in 834, with an average starting current of about 250 amps per motor.

.851 mph./sec. on level, with an average starting current of about 350 amps.

The notable performance of these locomotives, which results from their electrical characteristics has necessitated a special study of the mechanical part so as to ensure that the latter should be capable of meeting the duties imposed by the electrical equipment.

It may be pointed out here that, though the locomotives in question are primarily intended for hauling freight trains, the results obtained with them on fast service have been as good as in the case of the most modern express locomotives, both on straight track and on curves. This has been fully demonstrated by comparative tests made by the engineers of the Paris-Orleans Railway. These measurements were

The differences in the case of the various speeds must be ascribed to the fact that the measurements were made on different sections of the line.

These good riding qualities, in particular, constitute one of the special features which place this type of D. C. locomotive in the very front rank of modern locomotive design and render it both the most adaptable locomotive and that best capable of dealing with the most varied traffic of a great railway system.

We are reproducing here speedometer strips obtained on an express train Paris to Les Aubrais, which is hauled regularly by these locomotives. These strips give an accurate idea of the speed these locomotives can maintain.

We would further point out that the current consumption

•• mark for closed signal

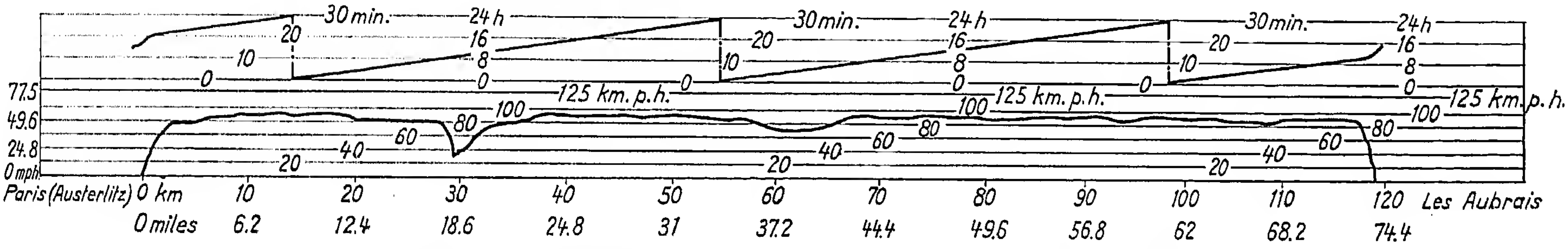


Fig. 6. Strip of a recording speedometer on the section Paris-Les Aubrais.
Southern Express. Trailing weight 397 tons.

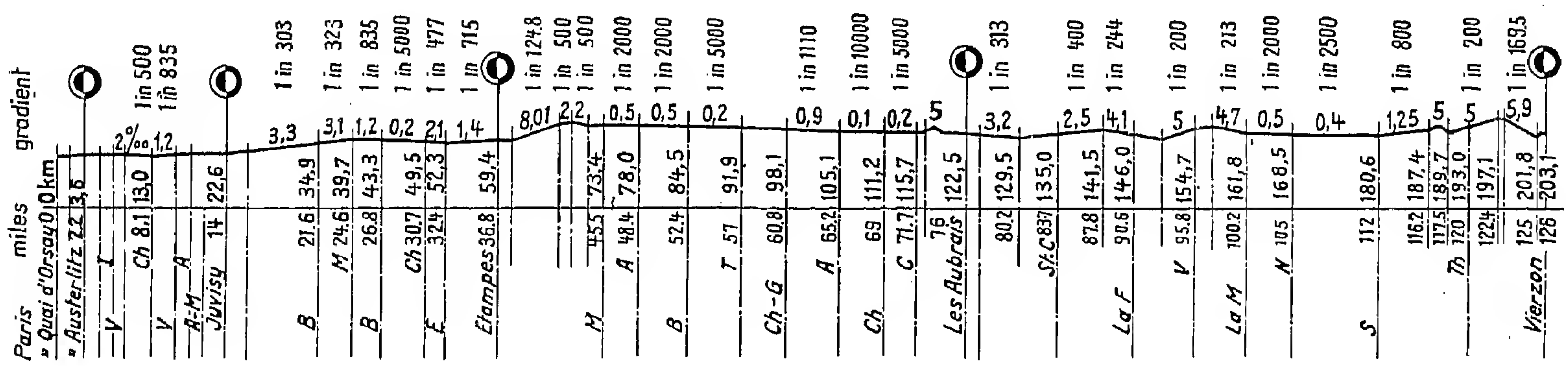


Fig. 7. Simplified profile of the Paris-Vierzon line.

made by means of a Hallade recording apparatus, on the Paris-Etampes line. The instrument was placed, for the purpose of comparison, first in the forward driver's cab of the locomotive running light and subsequently in the third compartment of a first-class coach, type AT8 with two bogies.

The ratio between the maximum amplitudes of the vertical displacements V and of the transversal displacements T, for the same distance travelled, at the same speed, can be obtained from the following table.

Speed m. p. h.	Coach AT8 T	Coach AT8 V	Locomotive EBB 103 T	Locomotive EBB 103 V
63.3	1	1	1.58	1.59
60.8	1	1	1.38	2.14
62	1	1	2.34	1.30
60.8	1	1	3.82	2.78
57	1	1	2.03	3.08

is very small, the latter being as an average (after deduction of the power consumption of auxiliaries) 19.3 watt-hours per ton-mile for series-parallel operation of motors (normal service) with a trailing load of 578 tons (39 goods trucks), a maximum speed of about 27.9 mph and an average working pressure of 1400 volts.

The tractive resistance measured on locomotive is plotted in curve 1 of Fig. 8; the curve 2 represents the theoretical tractive resistance obtained from the following formula:—

$$R_{\text{kgs/tons}} = 1.5\left(2.5 + \frac{V^2}{2500}\right).$$

We shall supplement these readings with a few figures taken during service on locomotives of this series.

a) Freight train MW Les Aubrais to Brétigny with stop at Etampes.

Trailing load	1135 tons (70 coaches)
Nominal speed	18.6 mph.
Maximum permissible speed	27.9 mph.
Time measured for the journey over the Aubrais-Etampes section	1 hr 52 min (39.1 miles)
Time measured for the journey over the Etampes-Brétigny section	53 min 30 secs (15.2 miles)
Power consumption measured with meter	945 kw-hours

b) Freight train MW Paris to Les Aubrais with stops at Brétigny and Etampes.

Trailing weight	960 tons (69 coaches)
Nominal speed	18.6 mph.
Maximum permissible speed	27.9 mph.

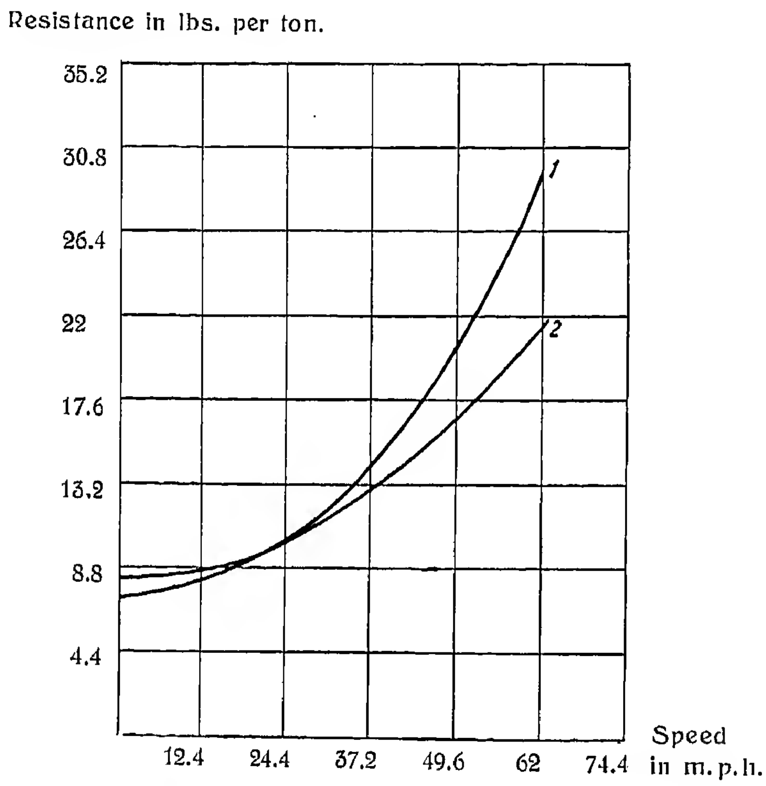


Fig. 8. Tractive resistance curves.

1 Test result

2 Curves obtained from formula

Time measured for journey over the Paris-Brétigny section	1 hr 9 min (19.4 miles)
Time measured for journey over the Brétigny-Etampes section	42 min (15.2 miles)
Time measured for journey over the Etampes-Les Aubrais section	1 hr 37 min (39.1 miles)
Power consumption measured with meter	1334 kw-hours

c) Fast passenger train Paris to Etampes with stop at Juvisy and Brétigny.

Trailing load	660 tons (18 coaches)
Nominal speed	43.4 mph.
Maximum permissible speed	55.8 mph.
Time measured for journey over the Paris-Juvisy section	17 min (11.8 miles)
Time measured for journey over the Juvisy-Brétigny section	13 min (7.45 miles)
Time measured for journey over the Brétigny-Etampes section	20 min (13.95 miles)
Power consumption measured with meter	790 kw-hours

Same train on return journey Etampes to Paris.

Time measured for journey over the Etampes-Brétigny section	21 min (13.95 miles)
Time measured for journey over the Brétigny-Juvisy section	11 min (7.45 miles)
Time measured for journey over the Juvisy-Paris section	17 min (11.8 miles)
Power consumption measured with meter	696 kw-hours

d) Express train Paris to Les Aubrais.

Trailing load	400 tons (10 coaches)
Nominal speed	43.4 mph.
Maximum permissible speed	55.8 mph.
Time measured for journey over the section in question	1 h 30 min (73.8 miles)
Power consumption measured with meter	1015 kw-hours

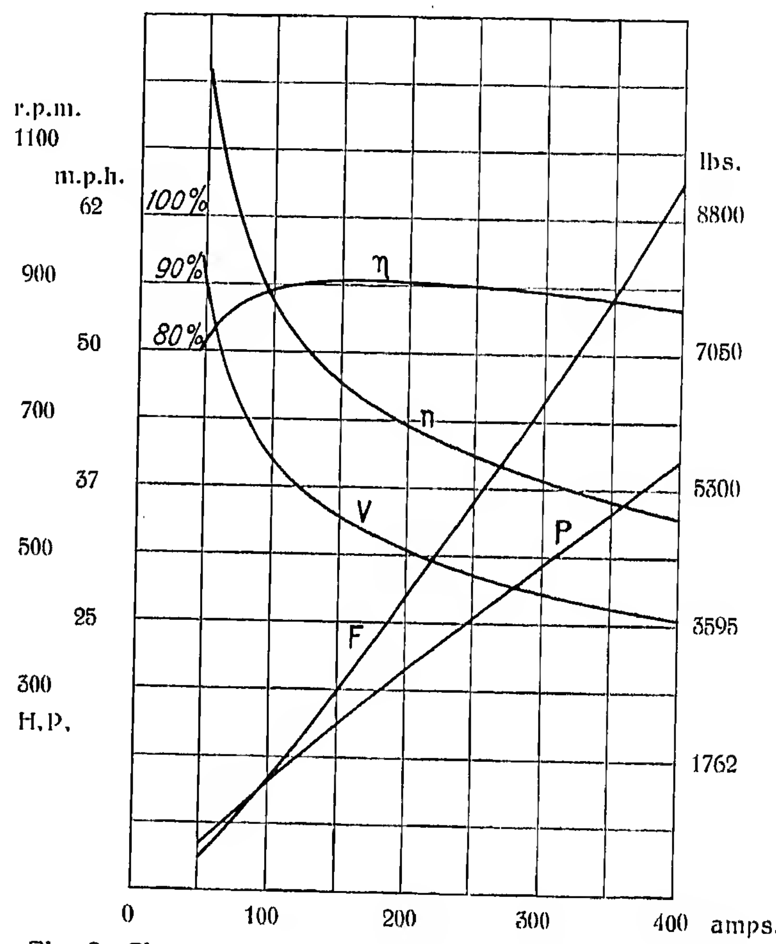


Fig. 9. Characteristics of traction motors Type TM 3301.

η = efficiency in %	n = r.p.m.
P = output in HP	100% field
V = speed in mph	Pressure 1350 volts
F = tractive effort in lbs	Gear ratio 1:3.47

Same train on return journey Les Aubrais to Paris.

Time measured for journey over this section	1 h 28 min (73.8 miles)
Power consumption measured with meter	695 kw-hours

It may be of interest to give here a few particulars regarding the traction motors; the characteristics of these machines are represented in Fig. 9. We shall further describe the main contactors which are designed for electro-pneumatic operation; these contactors, while permitting of the different modes of connection, afford an effective means of protection for the electrical equipment and the traction motors, in particular.

The value of 430 HP guaranteed by the Oerlikon Company as one-hour rating of the traction motors — a figure

which constitutes a record for motors for nose suspension and intended for standard gauge locomotives — has been fully adhered to, and the motors have proved amply dimensioned for that output, both from the electrical and mechanical point of view. On the other hand, the continuous rating of 330 HP laid down in the specification has been greatly exceeded during tests; it has, in fact, been possible by resorting to special forced ventilation to increase the continuous output to 375 HP.

The motors, as stated before, are arranged for nose suspension and provided with forced ventilation; they are fitted with two rows of brushes only. The reduction of field is obtained simply by cutting out field turns. The armature bearings are of the ring lubricated type, with lined bronze bushes, while the axle bearings are arranged for pad lubrication and provided with lined cast steel bushes.

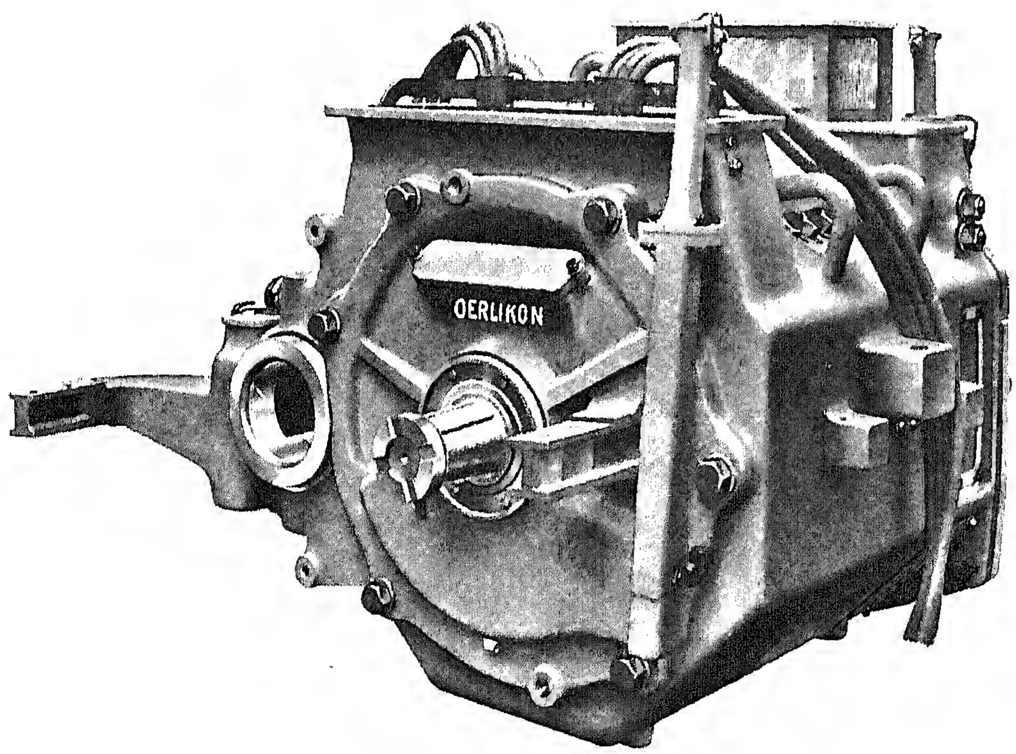
In view of the performance of these motors during service, it would seem that the formula used is that which gives the best results at the present stage of development of traction design. There is no need to point out the advantages derived from the use of two rows of brushes only, on motors with nose suspension; it may merely be mentioned that this arrangement greatly facilitates the maintenance of motors.

It might have been feared that, at speeds of 56 mph. such as come into question, under normal operation, when the locomotives are hauling express trains or produce trains, the use of two brush-holders only, on the motors, might give rise to disturbances in service, owing to the jerks to which the locomotives are subjected on the line; experience shows however, that with the two rows of brushes suitably arranged, entirely satisfactory results can be obtained even at high speeds.

As regards the design adopted with armature bearings and axle bearings, it seems to be the best and most reliable arrangement, as well as the most convenient, with regard to maintenance and the cheapest that can be devised at the present day, in the case of motors of the size in question.

It may be mentioned that, from the time these motors have been put into service up to the present day, there has only been one case where bearings have been found to heat, and this was due to insufficient lubrication owing to the loss of an overflow pipe. We would add that, as a test, the lubricating oil in the motor bearings of several locomotives was only renewed after a mileage of more than 31,000 miles, without this giving rise to any trouble or excessive wear of parts.

In spite of the very exacting duties which these motors have to perform and though several locomotives have already done a mileage of over 47,000 mile-trains, practically no wear has been observed in the bearings. Furthermore, the consumption in lubricant is very small. Under normal conditions, several thousand miles can be run without having to add any lubricant to the armature bearings, in particular; this gives an idea of the reliability in operation as



Traction motor, type TM 3301.

well as of the reduction in maintenance costs which can be obtained with these locomotives.

The type of drive adopted for these motors, in the case of the locomotives of this series, is one with single reduction gear without flexible coupling arrangement. We would however, mention that the first locomotive of this series was designed with flexible drive and double reduction gear.

The particulars and figures given above apply to the two types of locomotives, the results obtained being practically the same, in either case.

It can be said that the wear of gears has been very limited with both designs; in fact, at the present time, after more than three years service, no appreciable wear of gears has been observed.

Experience would, however, tend to show that, in certain special cases, preference could be given to a flexible drive with double reduction gear, as with this arrangement the non-sprung weight is reduced and the locomotives are thus rendered more suitable for high speeds; on the other hand, smoother starting up of locomotive is obtained.

As regards the main contactors, they are electro-pneumatically operated; it may be mentioned that this design of contactor was used for the first time by the Oerlikon Company on the locomotives EBB101 to 180 and has subsequently been adopted as standard on all Oerlikon locomotives for 1500 volts D. C. Contactors of this type are also utilised, for instance, on the express locomotive, type 2BB2 supplied by Oerlikon-Batignolles to the P. L. M. Railway, as well as on the 22 locomotives, type CC ordered from the Oerlikon Company by the Northern Spain Railway (Compañía de Los Caminos de Hierro del Norte de España).

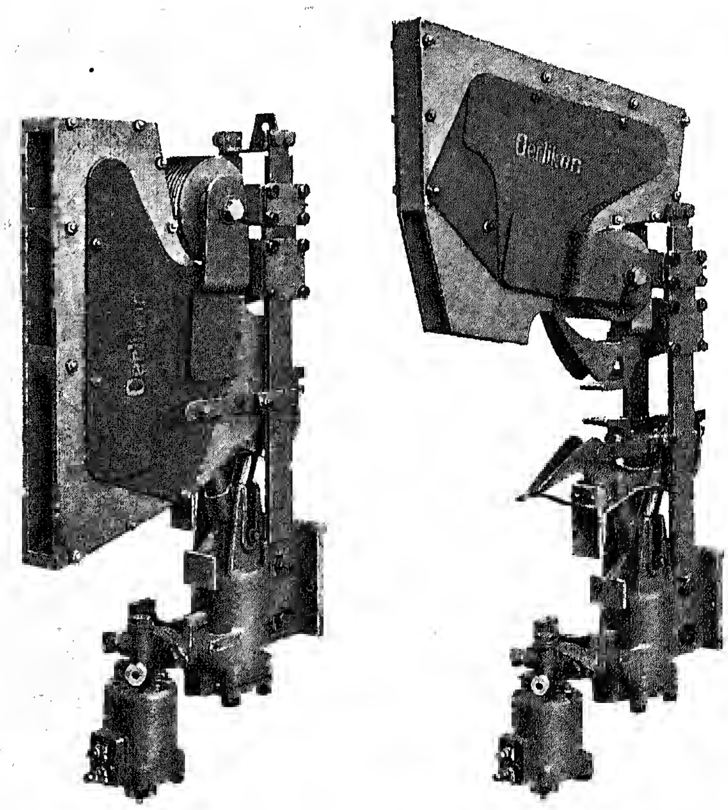
This shows conclusively that the gear in question has given entire satisfaction. Its advantages can be summarised as follows: robust construction, perfect insulation of body of contactor, very high speed and, consequently, great rupturing capacity, ready access to parts and very easy maintenance and overhaul of gear.

The illustrations to be found here give some idea of these various advantages. It may be stated that the contactors were guaranteed for a rupturing capacity of 1000 amps at 1500 volts; it has been possible, however, during the series of tests carried out at the substation of St. Michel s/Oise, of the Paris-Orleans Railway, to interrupt repeatedly a current of 5,500 amps at about 1500 volts. With two contactors in series, the rupturing capacity has exceeded 6000 amps at 1500 volts.

Owing to these remarkable results with regard to rupturing capacity and in view of the convenient arrangement of the train control equipment, it has been possible to dispense entirely with a quick-acting circuit breaker on the locomotives EBB101 to 180, as the contactors themselves replace such gear, and even present certain advantages from a practical point of view, specially with regard to interchangeability, simple construction and easy maintenance.

In order to form an idea as to the protection afforded by this gear, the Oerlikon Company carried out a series of short-circuit tests on the equipment of a locomotive. For these tests, one traction motor was earthed; the short-circuit output had to be limited to 6000 amps at 1500 volts, as the testing conditions at the substation did not permit of a larger output.

The results obtained during a number of consecutive tests were quite conclusive, as the interruption of current took place in an entirely reliable way; the total rupturing time obtained from oscillographs was about $^{4}/_{10}$ second. It



Contactor.

may be added that the contactor gear causes the interruption to take place in two stages; during the first stage, the starting resistances are introduced by the contactors controlling these resistances and the short-circuit current is reduced, while, during the second stage, the current is entirely interrupted by the line contactors.

We do not propose to deal here with the various details of the electrical equipments, but the information we have given regarding their essential parts, namely the traction motors and contactor gear, should give a general idea of the lines on which these equipments have been studied and constructed.

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

BULLETIN OERLIKON

No. 72 — June 1927

Contents: Glass bulb rectifiers.

Notes and News Items. Regulating resistances with large number of steps. — Helical fans.

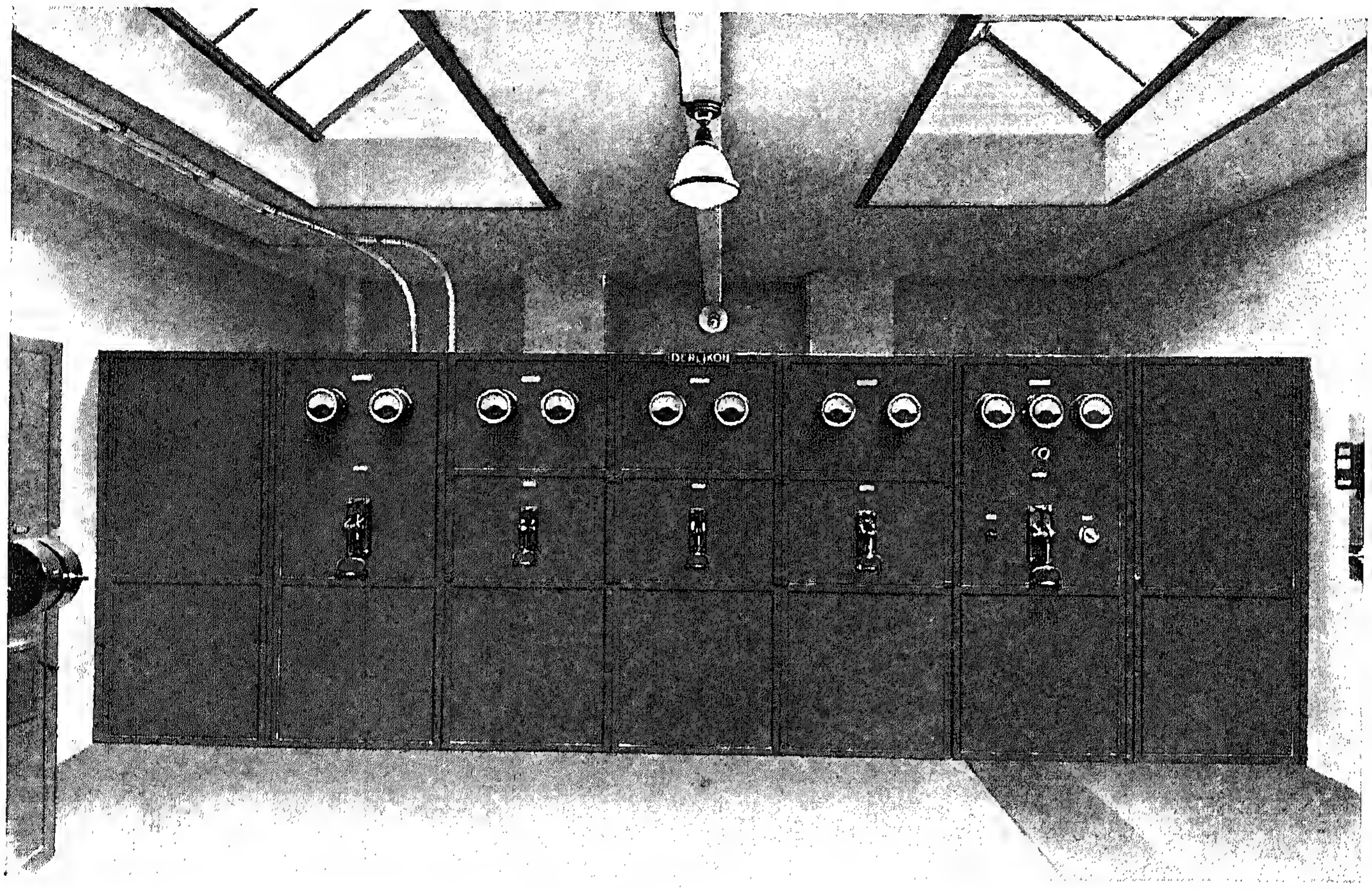


Fig. 1. Glass bulb rectifier plant for 400 KW, 500 volts, with 3 glass bulb rectifiers in parallel.

Glass Bulb Rectifiers.

As a result of the remarkable progress made in connection with glass blowing, it is now possible to manufacture bulbs of very resistant glass, for mercury rectifiers up to considerable outputs. A few years ago, the largest current for which glass bulb rectifiers could be built was 40 amps, at the present day, however, reliable equipments of this type can be made for capacities of 200 KW at 600 volts. There is, in fact, every likelihood that, before long, still larger outputs will be obtainable with glass bulb rectifiers, specially in the case of high pressures.

In view of the great possibilities of this plant, the Oerlikon Company have devoted much attention to the equipping of such installations, a number of which are now in operation.

The main object aimed at when disposing the plant is to make each bulb rectifier and its accessories an entirely self-contained unit. With this arrangement great simplicity is obtained and supervision becomes very simple; on the other hand, as these rectifiers lend themselves so easily for standby purposes, great reliability in service can be ensured without having to provide a large amount of spare plant. Furthermore, the provision of glass bulb rectifiers affords the simplest means of extending existing sub-stations, whether they be equipped with mercury rectifiers or with rotary converters, without great expenditure on structural alterations. It may be pointed out that even in sub-stations for large D. C. capacities, the installation of a certain number of glass bulb rectifiers may be a very economical proposition; this applies more especially to railway sub-stations where a large standby capacity is required. On the other hand, it is quite clear that the reliability in operation of an

installation is greater when it contains a large number of units in parallel, than when it is equipped with two or even one unit.

The provision of glass bulb rectifiers in sub-stations with large standby capacities presents the further advantage of necessitating only a small outlay, as compared with the total cost of installation — a very different case to that of rotary converters or metal mercury rectifiers. In such installations, the rectifiers are mainly used for standby purposes, as they constitute the part of equipment most liable to injury. It is thus possible, under these conditions, to provide an ample standby capacity at a relatively low cost, owing to the limited expenditure entailed by glass bulb rectifiers. The repair of glass bulbs is not costly; in fact, as a repaired bulb is as good as new, the makers replace damaged bulbs by new ones.

Glass bulb rectifier units consist, in the main, of a glass bulb with complete priming and excitation device, of a D. C. circuit breaker with overload and reverse current release, and of the necessary instruments. Fig. 2 represents such an equipment with a 500 volts, 350 amps. bulb. The priming of rectifier bulb is done by electro-magnetic means, the device in question being brought into play by a push button. When it is desired to parallel units, it is merely necessary to close the D. C. circuit breaker.

In view of the fact that mercury rectifiers are so simple in operation and easy to parallel, this type of plant is specially suited for use in automatic sub-stations. The Oerlikon Company have an installation of this description for the operation of their Works' railway; the equipment in question (Fig. 3) comprises two glass bulb rectifiers for 600 volts and 150 amps. The plant is switched on in the morning and requires no further attention. Automatic sub-stations with glass bulb rectifiers are characterised by great simplicity and, at the same time, great reliability, as all appliances for the measurement and checking of vacuum, water-cooling, etc., such as required for metal mercury rectifiers, are dispensed with.

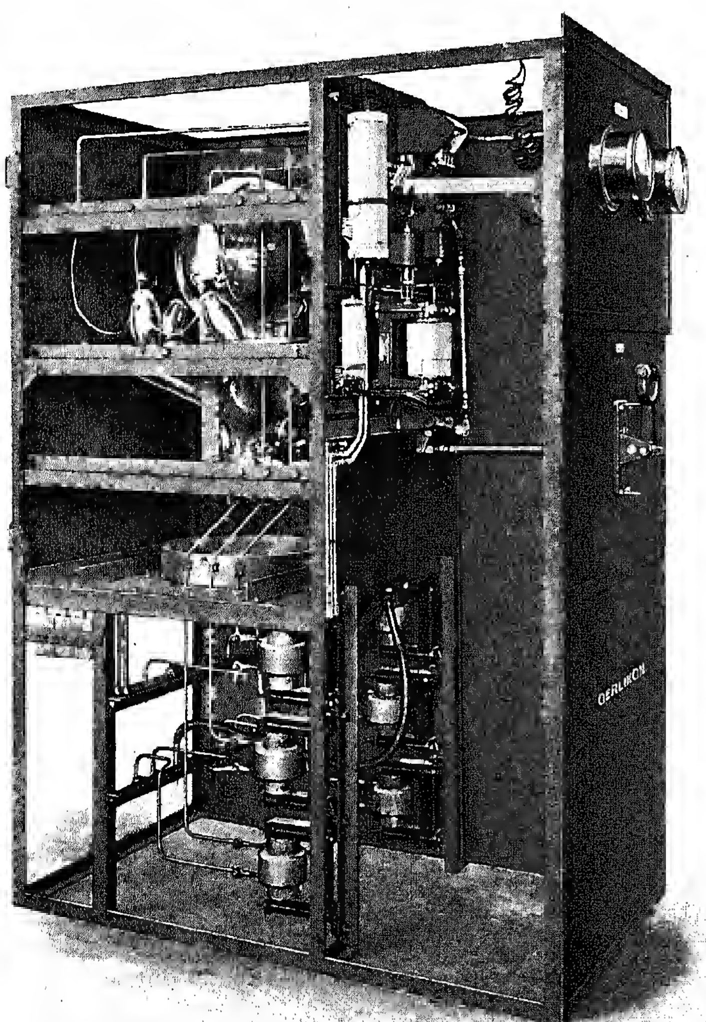


Fig. 2.

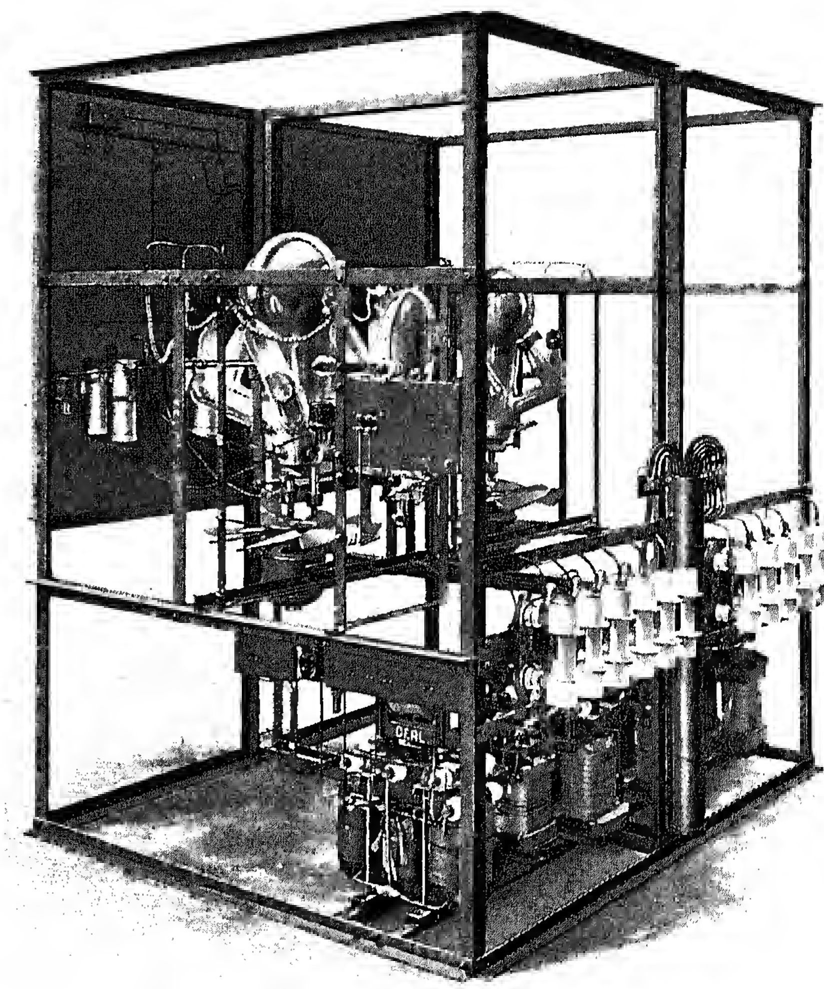


Fig. 3.

Fig. 4 is a single-line diagram of this installation. The plant is switched on by means of the switch, 1, or through the action of a time switch. The following switching operations then take place:—

1. Switching on.
   a) As a result of the closing of switch, 1, the relay, 2, comes into play and closes the circuit, 3, feeding the auxiliaries. The circuit breaker, 4, is switched on and pressure applied to the main transformer, 5.
   b) Both rectifiers I and II become alight automatically. The relay, 6, cuts out the priming device, as soon as the excitation starts to function.
   c) At the same time, the automatic circuit breaker of the rectifier I and the outgoing circuit are switched on. Current can now be supplied to system. The switching on and off can, of course, be made dependent upon the pressure of system.
2. Paralleling.
   When the load increases, the second rectifier is switched on automatically by means of the paralleling relay, 7. The relay with time adjustment, 8, prevents too frequent switching on and off in the case of a very fluctuating load. The rectifier is switched off when the load decreases.
3. Protection against overloading and short-circuits.
   In the event of short-circuits in the system, the current is interrupted by means of the overload relay, 9. The plant is then switched on again through the operation of the re-setting relay, 10. The switching on takes place tentatively at certain intervals of time. The minimum current relay, 11, prevents the switching of plant on a short-circuit.

   In the case of a permanent short-circuit, the whole installation is closed down. At the same time as the station is switched off, an alarm bell starts to ring in the nearest supervision post.

   The overload relay, 12, protects the bulb against overloading; this relay switches off the bulb in the event of prolonged overload, in which case the signalling device also comes into play.

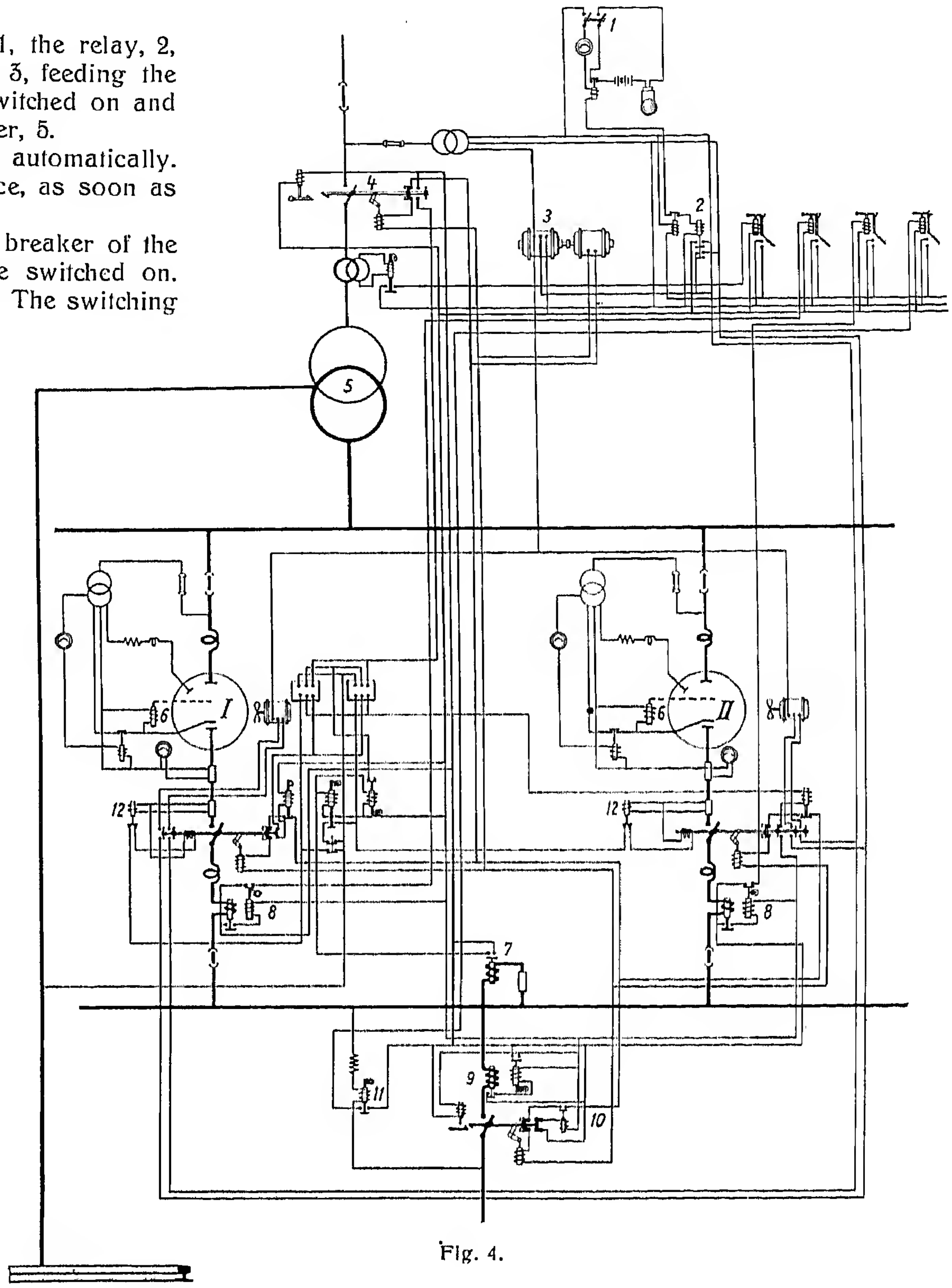


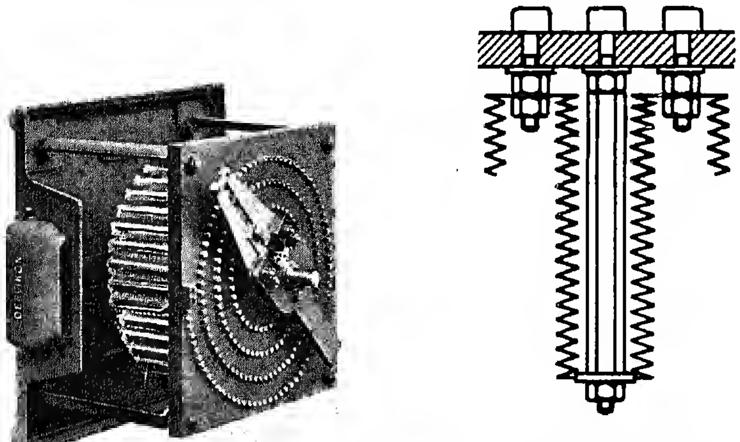
Fig. 4.

Notes and News Items.

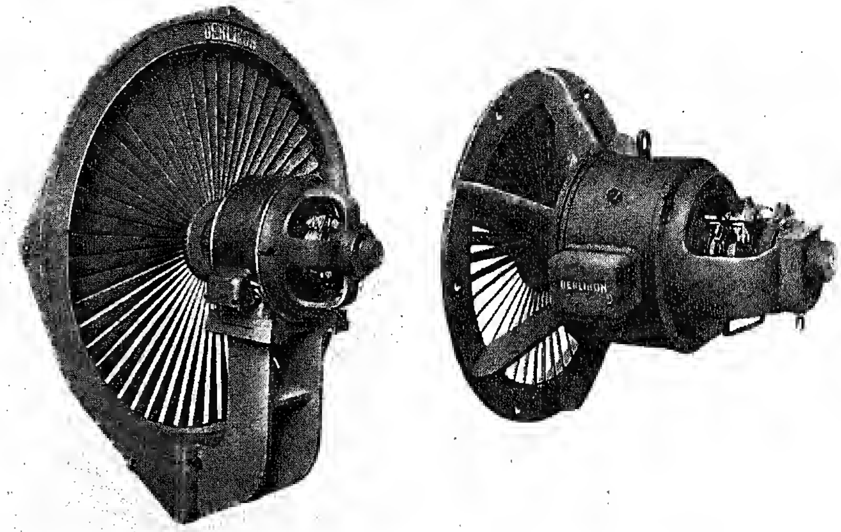
Regulating resistances with large number of steps. It is becoming more and more the practice to regulate the pressure of alternators by shunt regulation alone, that is to say, to provide a regulator only in the field circuit of exciter. In such a case, the main regulator in the field circuit of alternator is entirely dispensed with, so that installation and maintenance costs are reduced. On the other hand, the small shunt regulator is easier to operate than a main regulator.

In order to be able to keep the pressure of alternator constant between light load and overload, it is often necessary to regulate the terminal pressure of exciter over a range of 1:4. The adjustment of pressure within these limits entails the use, not only of a special type of exciter with regulating poles, but also of a regulator with a large number of steps. If this condition is not satisfied, the generator pressure can only be adjusted with difficulty, specially at light load or when the machine is working as an under-excited synchronous condenser, or not at all.

In order to meet the case, the Oerlikon Company build special regulating resistances with a large number of steps, which are both simple in design and easy to operate. The illustration given here shows one of these regulators with casing removed. With a view to obtaining the large number of steps required, the contact studs are arranged along a



Regulating resistance with large number of steps and detail drawing.



Figs. 1 and 2. Helical fans with motor arranged on bracket (left) and overhung (right).

spiral path; this makes it possible, to use the length of the circumference several times over. The contact on the arm, which moves over the studs, is arranged in such a way that it can slide between two guides; it is carried by an insulating support gripping the studs on either side. In view of this, the moving contact is forced to follow the spiral path when the hand-wheel is operated. There is further a fixed contact on the regulator arm, which slides over a contact ring and serves to lead the current to the terminals of regulator.

The sections of resistances corresponding to the individual steps consist of helical elements and are linked up directly to the studs. Every other stud is connected to the base of the helical resistance, and the stud in between, to the support of resistance; the latter is arranged as shown in the above illustration. It is thus possible to dispense with special connections between resistance and contacts.

With the design in question, a large number of contacts and the corresponding resistances can be concentrated within a relatively small space. The number of studs amounts to 100, 500 or 1000 according to the size of regulator; the number of turns of hand-wheel required to cover the whole contact path varies, of course, accordingly. The regulator illustrated above, for instance, has 240 studs; the necessary number of turns is 3.8.

In order to show the position of the moving contact at any time, a special position indicator is provided; the latter can either be fitted directly on the regulator or mounted on the switchboard. The reduction gear of the indicating device is so designed that the displacement of pointer does not exceed 360° even when several turns have to be made with the hand-wheel; on the other hand, both motions take place in the same direction. The attendant thus sees, in the case of any adjustment of regulator, in which direction he has to turn the hand-wheel in order to raise or lower the pressure.

The apparatus we have described can, of course, be used for other purposes than that of regulating the pressure of alternators; it can be built, without alteration in design, for the speed regulation of shunt wound D. C. motors or for controlling drives of paper machines.

Helical fans. The helical fans built by the Oerlikon Company are so designed as to ensure a flow of air as far as possible free from eddies; owing to this, the efficiency of fan is greatly improved. As can be seen from Fig. 1, the fans consist of three parts, namely, the blade wheel, the frame and the motor bracket, the two latter being bolted together. This arrangement with motor secured to the frame through the intermediary of a bracket presents the advantage of permitting of the use of brackets of different dimensions according to the size of motor.

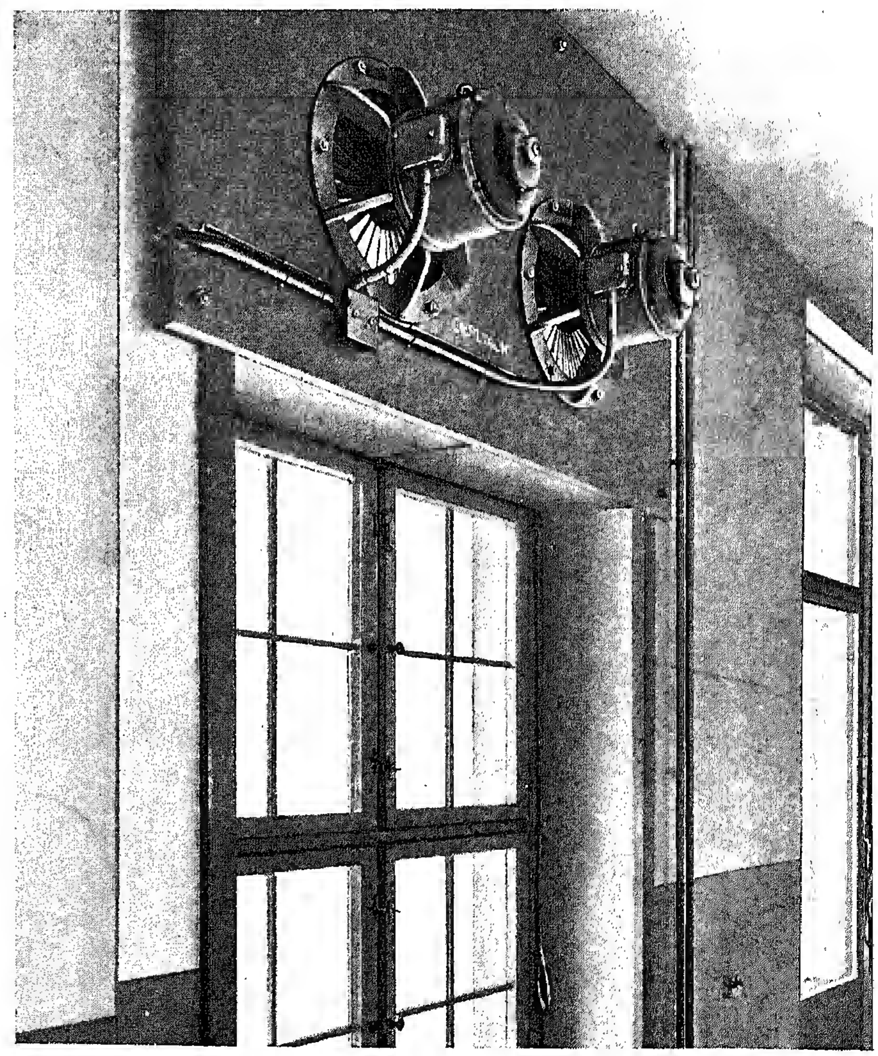


Fig. 3. Helical fans in position.

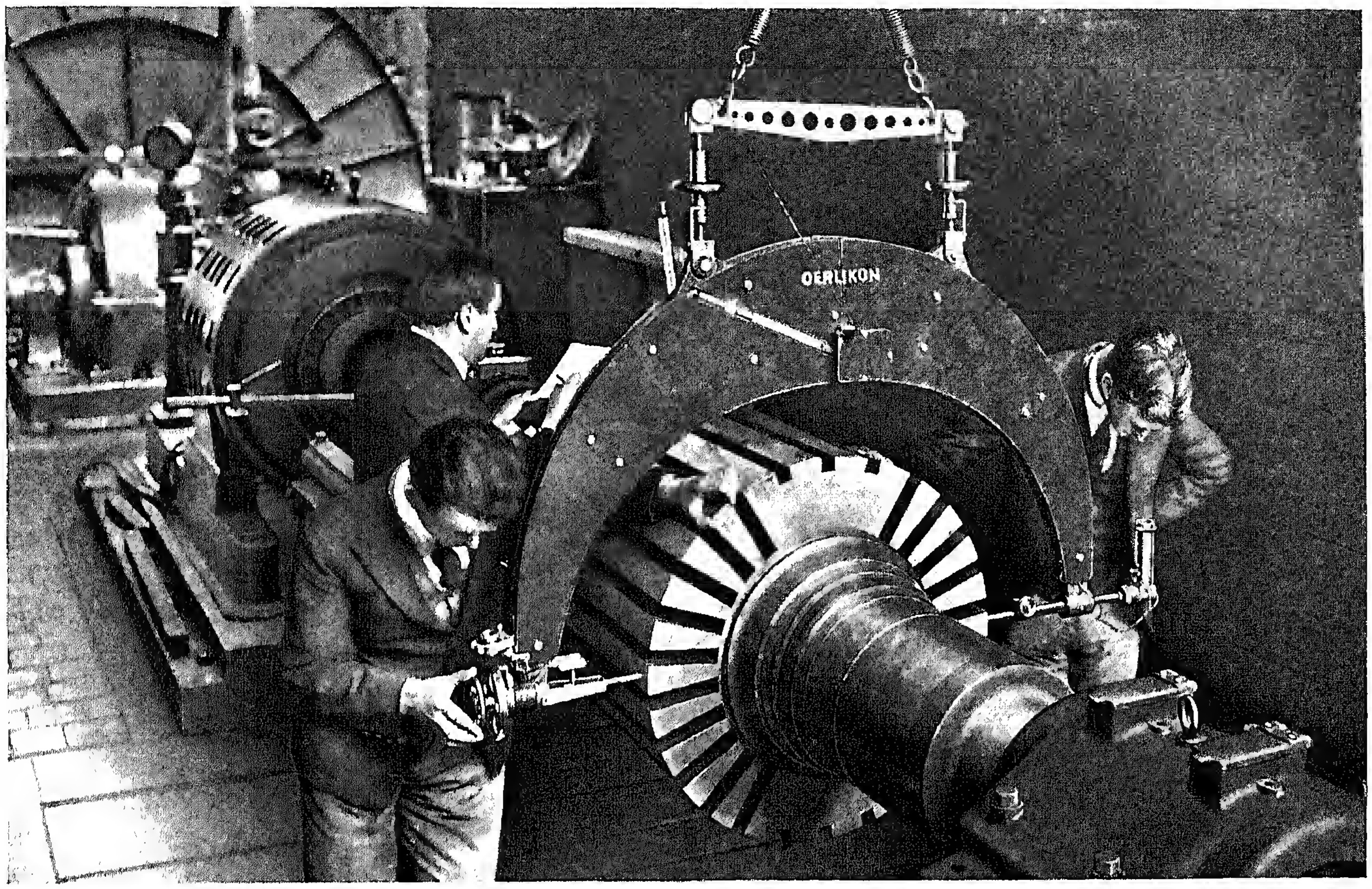
In recent designs, however, the bracket is omitted and the frame is connected directly to the motor flange, in which case the motor is made without feet and mounted overhung. Fig. 2 shows such a fan. The arrangement in question is very compact while the efficiency of equipment is high and its price low. Fig. 3 shows the very simple way in which these fans can be mounted.

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

BULLETIN OERLIKON

No. 73 — July 1927

Contents: The question of safety of large turbo-generators.
Testing by the pressure impulse method. Equipment for 300 KV_{max} at the Oerlikon Works.



Rotor body of a large 3000 r. p. m. turbo-generator undergoing test for determining permanent expansion.

The Question of Safety of Large Turbo-Generators.

In view of the trend of recent years to build turbo-generators of ever increasing capacity, the question of safety is taking precedence, more and more, over all other considerations, such as efficiency, for instanee, as such plant necessarily represents a very large capital outlay, while any breakdown of these machines may further result in very serious damage to installation. The most important preeaution when designing and building large turbo-generators of 3000 r. p. m. is to ensure that the rotor body can safely withstand the enormous eentrifugal forces to which it is subjected. The fact that explosions of rotor bodies have occurred from time to time during the last years shows that security in this respect has not been attained in all cases.

The Oerlikon Company have always paid the greatest attention to this matter and preferred to saerifice other advantages rather than to depart from fundamental principles which many years' experienee have proved to be correct. In the case of the rotor bodies of large standard 3000 r. p. m. units, the stresses in all parts are relatively very small, as can be seen from the table below; we are giving there, for instance, the stresses and tensile strength of material for the largest of these standard sizes, with capacities of about 20 to 30000 KVA, at 3000 r. p. m.

		Stresses	Tensile strength
Rotor teeth		4.26 tons/sq.in.	47.7 tons/sq.in.
Innermost fibre in the central bore		8.88	47.7
Protective cover for the ends of rotor winding		13.34	54.1
Slot wedges	Bending	1.20	12.7
	Surface pressure	2.31	12.7
Compression in the case of the uppermost insulation layer (micanite)		.76	—

These values of stresses which are, according to the various data published, very small as compared with those of other makes, have been attained, in the main, through the use of aluminium strip for the rotor winding — a mode of

construction utilised by the Oerlikon Company as far back as some eight years ago*). The adoption of rotor windings of aluminium in the case of large 3000 r. p. m. units for more than 10000 KVA, with a view to increasing the degree of safety, was greatly facilitated, owing to the very good ventilation obtainable with the Oerlikon rotor design; there was, therefore, no difficulty in ensuring the dissipation of the additional heat, due to the excitation losses being about 50 % greater in the aluminium winding than in the copper winding. It may further be mentioned that the individual coils are joined up by means of autogenous welding according to a special process, and that the joints are as secure and easy to make, as soldered connections of copper strip; in fact, more than eight years have elapsed without a single defect occurring on such aluminium windings.

Even in the case of still larger 3000 r. p. m. machines — 50000 KVA units have, for instance, already been designed and tendered for — the stresses at 3000 r. p. m. are also kept low, as can be seen from the following table:—

		Stresses	Tensile strength
Rotor teeth		4.32 tons/sq.in.	47.7 tons/sq.in.
Innermost fibre of the central bore		10.4	47.7
Protective covers for the ends of rotor winding		15.87	63.6
Slot wedges	Bending	.95	12.7
	Surface pressure	2.54	12.7
Compression in the case of the uppermost insulation layer (micanite)		.88	—

Apart from keeping the stresses low, the Oerlikon Company utilise a very accurate method for making sure that the rotor body is perfectly sound. The usual way of ascertaining whether a rotor body is safe is to subject the rotor, after completion, to an overspeed test in an explosion proof chamber. If the rotor withstands this test, it is regarded as "safe" and passed for delivery, without troubling whether it has suffered in its structure, as a result of this severe test. The method used by the Oerlikon Company, makes it possible, however, to obtain quite definite data regarding the condition of material, quite apart from the mere overspeed test.

After the rotor body has been received from the steel works, with bore along its centre, and numerous tangential and radial tensile and bending tests have been carried out by experts to make sure that the strength of material complies with the specified values, the bore is examined by means of a special optical instrument, with a view to ascertaining whether there are any hollows or other faults in the material. It is only once this test has shown that the interior of rotor is perfectly sound, that the first machining operation is carried out.

After the winding slots have been cut out, and before the ventilation slots are made, the rotor body is subjected to overspeed tests at increasing speeds. When the rotor body is in this condition, stresses in it are exactly the same as for a completed rotor with its aluminium winding. The procedure with the method of testing in question is essentially as follows:— The diameter of the rotor body is measured at different points, before and after each test, with a precision micrometer specially built for the purpose, in order to be able to ascertain any permanent expansion, before overstraining of material takes place or any danger arises. The instrument used for this purpose permits of measurements with a degree of accuracy of $^1/_{1000}$ of a millimetre ($^1/_{25400}$ of an inch). The measuring points are of course finely machined so that this degree of accuracy can be obtained. It is a well-known fact that every stress in material gives rise to a non-permanent elongation, as well as to a very small permanent extension, long before the limit of proportional elongation or even the yield point is reached. This value of permanent extension is, however, at the beginning so small that even on large parts, it can only be measured exactly by means of instruments permitting of the above accuracy. The diameter of rotor is first measured before the overspeed test, at various points accurately fixed, this being done, as in the case of all other measurements, after the temperature of rotor body and measuring instrument have been carefully equalised; the temperatures are measured by means of calibrated and finely graduated thermometers. The difference in temperature at the time of readings must not exceed $^1/_{10}$ ° C.

A 3000 r. p. m. rotor is first run at about 2500 r. p. m. and after the temperature has been equalised, a reading is taken again. The speed is then increased to 2900 r. p. m. and a further measurement made, and so on at 3200, 3400, 3600 and 3750 r. p. m. It is only when there is no permanent expansion exceeding permissible limits, after the overspeed test at 3750 r. p. m., that the rotor body is passed for manufacture and further machined and wound. Fig. 1 shows a rotor body undergoing such a test. The measurements are, of course, all carried out at exactly the same pressure, the latter being indicated by a so-called "minimeter". The man watching the minimeter keeps the instrument in a frictionless condition by gently tapping it with a finger, while the attendant operating the micrometer increases the measuring pressure by slowly turning the handwheel until the man at the minimeter signals that the desired pressure has been reached. A reading is then taken on the micrometer. The corresponding scales and verniers are illuminated by means of small electric lamps and read through fixed magnifying glasses. As the measurements are made with so high a degree of accuracy, any defect is revealed by the increasing permanent expansion, long before the material itself is damaged, and there is absolute certainty, when a rotor has been passed, that it has no overstrained places as a result of these tests. In this way, it is possible to guard against such causes as may lead to destructive explosions in service. If permanent expansion exceeding permissible limits occurs before reaching the highest speed of overspeed test, the trials are, of course, discontinued and the rotor is at once rejected.

During tests carried out recently on a rotor with a diameter of body of 920 mm. (3′ 0$^7/_{32}$″), the values of the final permanent expansion at 5 points were 0.0086, 0.0093, 0.0097, 0.0104 and 0.0073 mm., that is to say, as an average, only $^1/_{1000}$ %

*) See also "New developments in the design of turbo-generators" by H. Rikli, in the Revue Polytechnique Suisse of 28th. October 1922, and "On large 3000 r.p.m. turbo-generators" by H. Rikli, in the Bulletin de l'Association Suisse des Electriciens, No. 8, 1924.

of the length measured. Even if the expansion of rotor body had reached a multiple of this value, the rotor could have been regarded as "safe".

The rotor once completely wound is further tested three times at 25 % above normal speed with the winding heated to a temperature of 120° C.

(To be continued in next issue).

Testing by the Pressure Impulse Method.
Equipment for 300 KV_{max} at the Oerlikon Works.

The pressure impulse method of testing H. T. materials is a process which has been gaining very much in importance of late. This is due to the fact that, in the case of many parts of H. T. plants, it is often only possible to obtain accurate data regarding the efficacity of insulation, under service conditions, by determining the dielectric strength of this insulation when subjected to pressure impulses of short duration and following each other very rapidly. This applies, for instance, to the insulation between turns of the windings of all electrical machines and of transformers, in particular.

The tests carried out in the H. T. laboratory of the Oerlikon Company have shown that the surge tests prescribed in standard regulations could not furnish sufficient data for arriving at the dielectric strength of insulation between turns of machines and transformers, in the event of pressure surges*). In view of this, the Oerlikon Company have installed, in their department for the testing of materials, a special equipment for producing H. T. pressure impulses. We are giving below a brief description of the equipment in question.

The diagram of connections of installation is given in Fig. 1. The two condensers C_1 and C_2 are charged negatively and positively respectively through the H. T. valves V_1 and V_2, and V_3 and V_4, by the transformer Tr. The charging of condensers continues until the pressure between them causes the priming spark gap F_1 to come into play. The large and very rapid equalising current which results causes the desired pressure impulses in the resistance R of the oscillating circuit C_1, R, C_2, F_1; the shape of this pressure impulse can, in practice, be determined in a sufficiently accurate way. The maximum value of the pressure impulse is measured by means of the measuring spark gap F_2. The object O to be tested is connected in parallel with the resistance R. The value of the pressure rises from zero to its maximum in about $^1/_{10\,000\,000}$ of a second. This very rapid rate of increase corresponds to that of a periodical sinusoidal oscillation of about 2500000 cycles per second. The rate at which the pressure decreases is considerably less, but is still very high in comparison with a sinusoidal oscillation of 50 cycles per second.

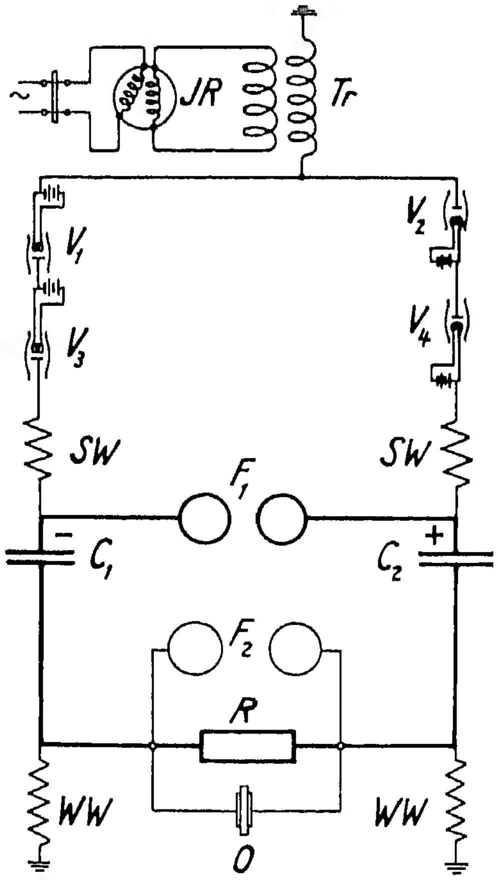


Fig. 1.

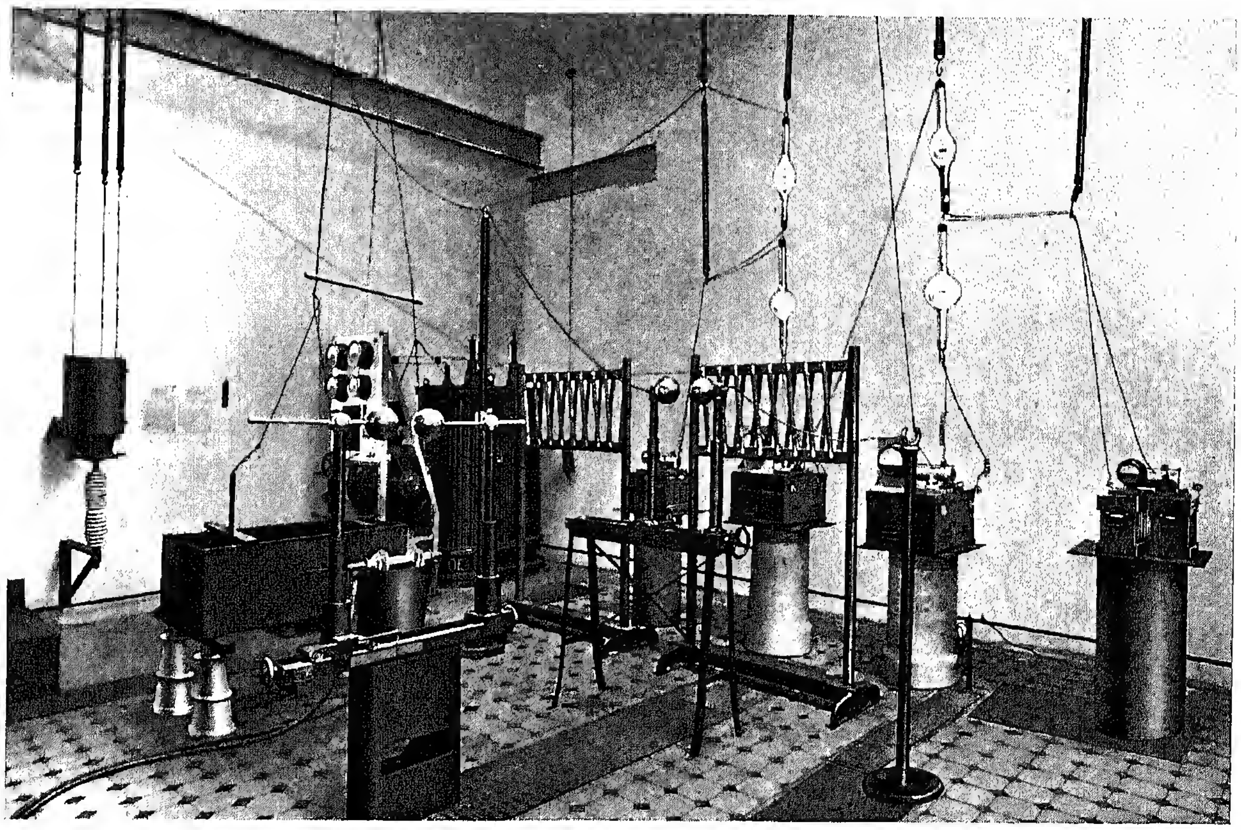


Fig. 2.

Fig. 2 is a view of the test room. The two sets of two H. T. valves in series can be clearly seen; these valves are heated by means of insulated lead accumulators. The priming spark gap F_1 is in the centre of the illustration, and the measuring spark gap F_2 on the left. The latter spark gap, the resistance R and the object to be tested are to be connected together by means of thick conductors as short as

*) "Comparative surge tests and puncture measurements on the winding of a 3000 kVA, 60 kV transformer" by Dr. M. Wellauer, in the Journal of the Association of Electrical Engineers, Vienna, No. 3, 1927.

possible. All the other connections forming part of the oscillating circuit are likewise to be as short as possible. The two condensers C_1 and C_2 are mounted above the roof of test room, and shown on Fig. 3. Each condenser consists of a number of screens with large surface, made of wire netting with small mesh, mounted on supporting insulators. This new design of condensers has given excellent results. The condensers are entirely free from Corona effect. The value of the capacity and of the puncture pressure can be varied within the widest limits. This design was adopted, as it was found from tests that glass and liquid condensers, such as in the case of thin insulation and low puncture pressures up to 30 kV, the frequency of impulses had no noticeable influence. The dielectric strength was only dependent upon the total number of impulses, no matter whether the impulses followed each other rapidly or slowly. This can be explained by the fact that the duration of the impulse itself is so very small, as compared with the intervals between impulses for 50 impulses per second. The frequency of impulses is regulated by increasing the A. C. pressure more or less above the D. C. pressure to be obtained. The number of impulses per second is determined by means of oscillographs. Fig. 5

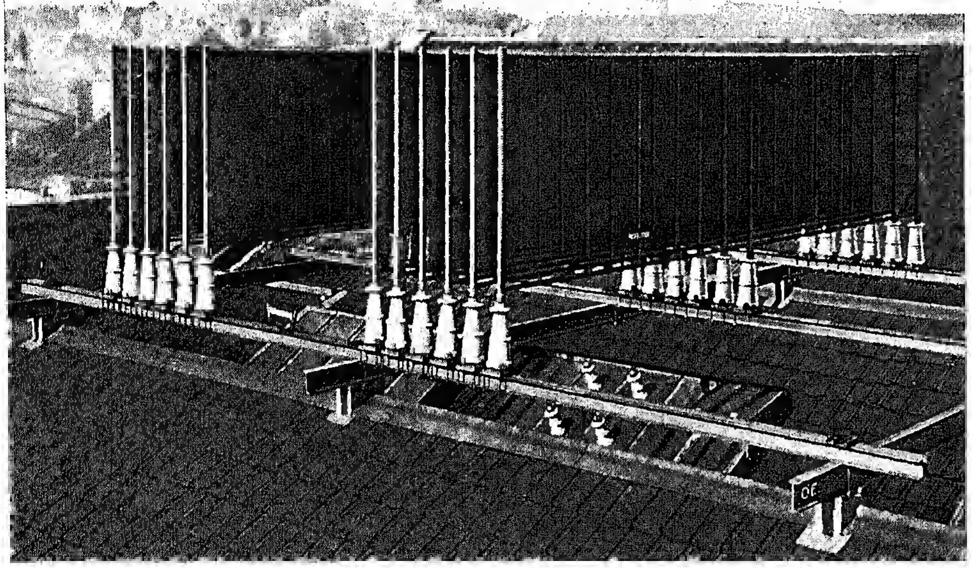
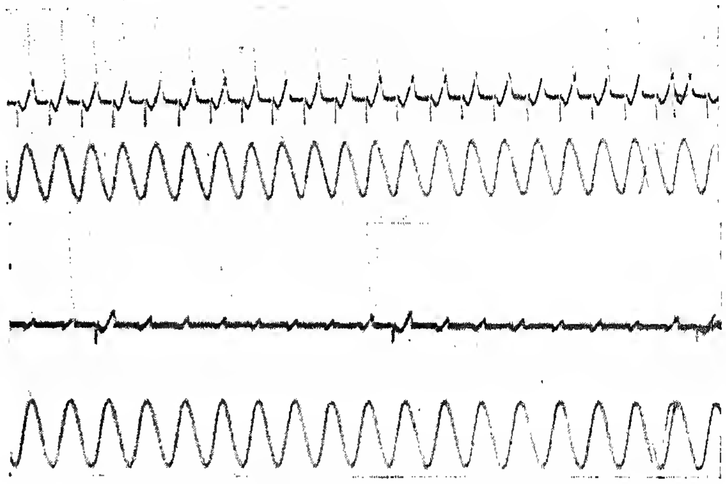


Fig. 3. Condensers mounted on the roof of test room.



Figs. 5 and 6. Oscillographs for 50 and 50/8 impulses per second, respectively.

Curve a — Copper bars, $\frac{6.5\times4}{7.8\times5.3}$ mm, 9 × paper, 1 × braided

Curve b — Copper bars, $\frac{7\times4}{9\times6}$ mm, 15 × paper, 1 × braided

Curve c — Copper bars, $\frac{7\times4}{10.9\times7.9}$ mm, 30 × paper, 1 × braided

a* b* c* Puncture values for 50 cycle A. C. pressure, applied during one minute.

The points with arrows directed upwards correspond to readings, for which puncture had not yet occurred after 3000 impulses; the arrows denote that the actual puncture pressure is higher.

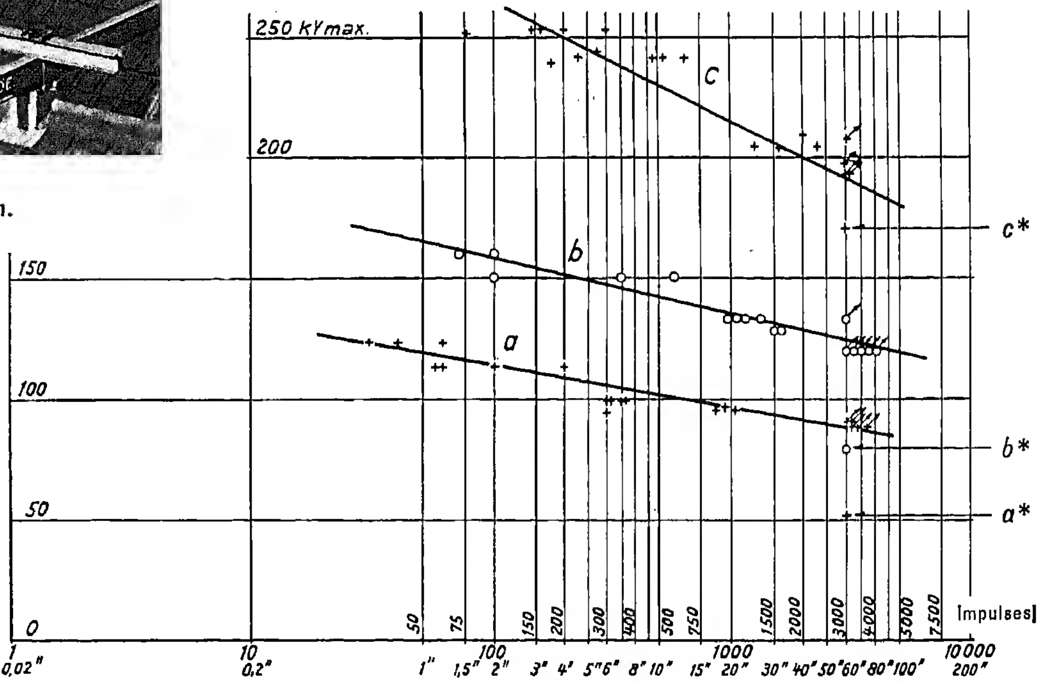


Fig. 4. Pressure impulse tests — Conductor to conductor, in oil at 16° C.

obtainable, were destroyed after a short time by these pressure impulses.

In Fig. 4, three curves have been reproduced giving the puncture pressures in function of the time, for paper insulation between the turns of a transformer winding. A notable feature is the small variation in the value of the puncture pressure. Exhaustive tests have been carried out with a view to finding out the influence of the frequency of impulses on the puncture pressure. For this purpose, the number of impulses was varied between 6 per minute, i. e. 0.1 per second and 50 per second. The preliminary results have shown that, represents an oscillograph for 50 impulses per second, i. e., for the case where the charging of condensers takes place so rapidly that, at every cycle, a discharge occurs across the priming spark gap F_1. The periodical oscillation in the oscillograph is the 50 cycle calibration curve serving as time scale. Fig. 6 shows an oscillograph taken in the case of a frequency of impulses of $^{50}/_{8}$ per second.

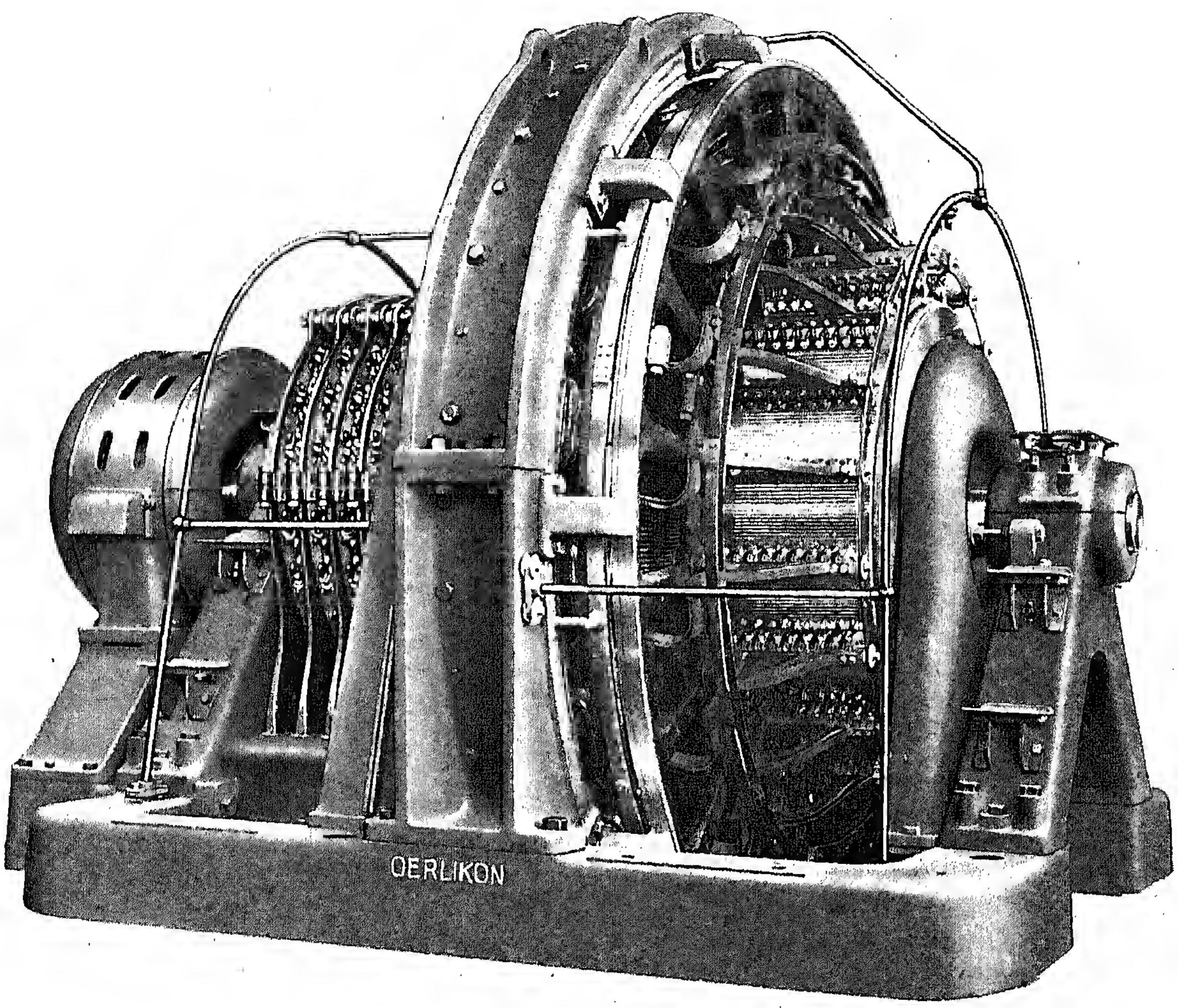
The testing installation in question is to be equipped very shortly for higher pressures than 300 kVmax. We shall give, in a subsequent issue, further particulars regarding the results of tests on H.T. material carried out with the plant described.

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

BULLETIN OERLIKON

No. 74 — August 1927

Contents: New rotary converters. — Compensated three-phase motor with additional slip. — The question of safety of large turbo-generators.



5000 KW rotary converter for 10000 amps., 500 volts.

New Rotary Converters.

The Oerlikon Company have recently supplied various rotary converters, which are of particular interest, in view of their special duties, large capacity or high pressure on D. C. side. A rotary converter with a continuous rating of 2300 KW at 460 volts, 5000 amps. has, for instance, been supplied for the production of zinc by electrolysis, while a rotary converter for 2500 KW, 2×165 volts, 7500 amps., another for 4000 KW, 500 volts, 800 amps., and a third for 5000 KW, 2×250 volts, 10 000 amps., have been built for the manufacture of synthetic ammonia. On the other hand, the Oerlikon Company have supplied, for traction work, rotary converters for 500 KW at 550 volts, for 1000 KW at 660 volts, for 500 KW at 900 volts, for 400 KW at 1200 volts, for 300 KW at 1350 volts, and for 750 KW at 1500 volts.

All machines have given excellent results under very severe conditions of service. The Oerlikon Company have further recently received an order for the complete electrical equipment of all the sub-stations of a Spanish railway, the Ferrocarriles Vascongados, connecting San Sebastian with Bilbao, high-tension D. C. being adopted there as traction system. The sub-stations are fed with three-phase current at 29000 volts, 50 cycles, which is converted into direct current by means of rotary converter equipments. These rotary converters are notable, both as regards capacity and pressure. They are designed for a continuous output of 1200 KW and for a terminal pressure of 1750 volts on the D. C. side; the overload capacity prescribed is 50 % for one hour and 100 % for three minutes, without exceeding the permissible temperature limits.

Compensated Three-phase Motor with Additional Slip.

Ordinary three-phase induction motors, without special devices for increasing the slip, have pronounced shunt characteristics, and are thus little suitable, when in that form, for driving rolling mills. In order to be able to utilise the moving masses of the rolling mill, for damping the sudden variations in load, and thus prevent too heavy fluctuations in current in the system, the characteristics of the machine must be such that the speed of the driving motor drops when the load increases. This means that the motor must have a sufficient slip.

It is a well-known fact that the slip of induction motors is proportional to the energy transmitted electrically to the rotor circuit of induction motor. In the case of an ordinary induction motor, the rotor winding is, under normal conditions, short-circuited; consequently, the electric energy transmitted to the rotor is purely represented by the ohmic losses in the rotor circuit. In order to increase the slip, resistances can be inserted into the rotor circuit. With this method of slip regulation by means of resistances, part of the energy transmitted electrically to the rotor is wasted in the resistances; as a result, the efficiency of plant is reduced.

The mode of regulation adopted by the Oerlikon Company consists in the use of a series-excited, compensated frequency changer. This method presents two special advantages over slip regulation by means of resistances. In first place, the regulation of slip takes place entirely automatically and without losses; secondly, an improvement of the power factor of system can also be obtained as the machine can work with leading power factor up to high overloads.

The compensated frequency changer permits of the utilisation of the electric energy transmitted from stator to rotor when the motor is working with a large slip. It thus avoids the wastage of energy in slip resistances. The counter-EMF for neutralising the excess in slip pressure is provided here by the compensated frequency changer, instead of by resistances, and can be adjusted for the same phase and value; the power absorbed by the frequency changer is returned in the form of mechanical energy and is available again on the shaft of the motor. The fact that this slip energy is returned in the form of mechanical energy and not fed back into the system, as, for instance, in the case of compensated frequency changers not coupled to the motor, renders the former arrangement specially suitable for operation at constant load under variable torque.

It is possible, apart from ensuring slip regulation, to cover the wattless component of motor, as the necessary excitation can be provided from the rotor circuit by adjusting the phase of the counter-EMF of the compensated frequency changer accordingly; in fact, the motor can even be made to work with a leading power factor. In the latter case, a pressure must be applied in the rotor circuit, which has a phase displacement of 90° in relation to the slip-EMF. The resulting counter-EMF of the compensated frequency changer will thus be made up of a component, which ensures the slip regulation — directly opposed in phase to the slip-EMF in rotor circuit — and another component displaced through 90° in relation to it, which supplies the necessary magnetis-

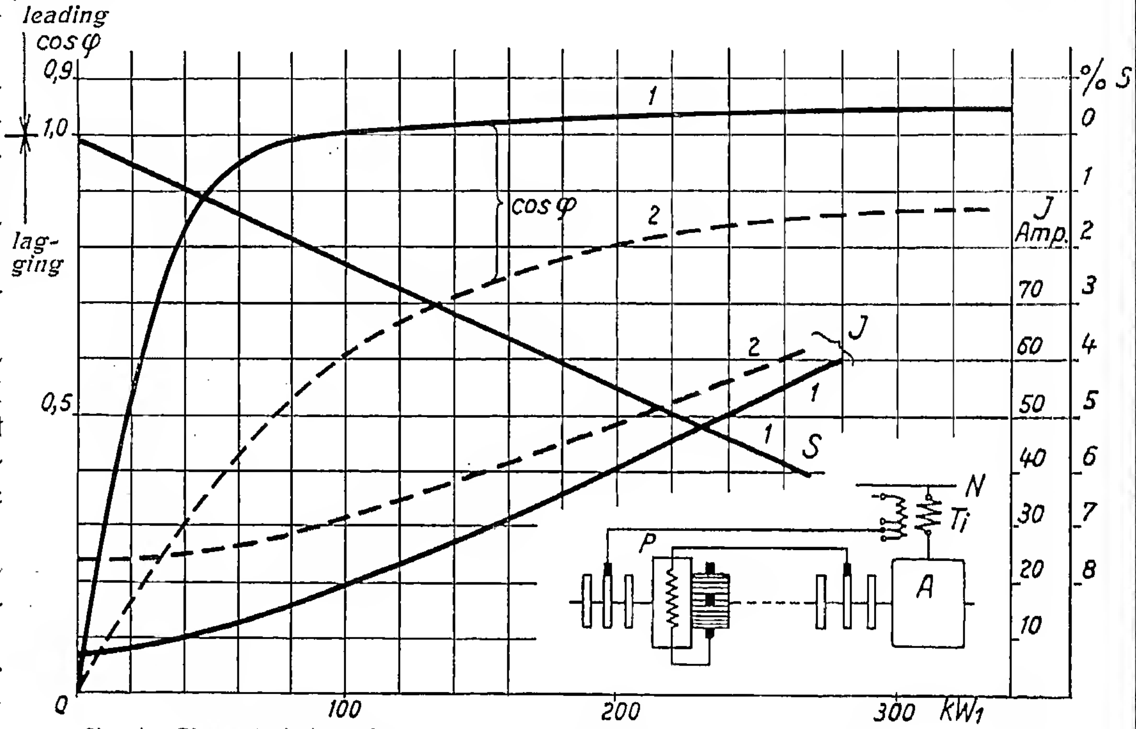


Fig. 1. Characteristics of motor (1 with compensator and 2 without compensator) and single-line diagram of connections of equipment.

ing current. Fig. 1 contains a single-line diagram showing the mode of connection of the induction motor and the series-excited compensated frequency changer. The induction motor is designated by A. The transformer Ti, for the excitation of frequency changer, is connected in series between the motor A and the supply. The compensated frequency changer P is coupled directly to the shaft of the induction motor, when the number of poles of both machines is the same, or through gears when the number of poles is different, in order to ensure that the frequencies of the counter-EMF of frequency changer and of the slip pressure of induction motor are identical at all speeds.

The arrangement of frequency changer with compensation winding, adopted by the Oerlikon Company, is that devised by Milch as far back as the beginning of the century. The frequency changer itself is built, in a general way, as an induction motor, with the difference that it has an armature similar to that of a rotary converter, with commutator and sliprings. A three-phase brush equipment is provided on the commutator side, and connected in series with the compensation winding on the stator. The compensation winding in question serves to neutralise the ampere-turns of the armature winding, due to the rotor current of induction mo-

tor. Owing to the provision of the compensation winding, it is only necessary, for obtaining a counter-EMF in the frequency changer, to supply a small amount of magnetising energy at the sliprings of the frequency changer, for instance.

The frequency changer is connected, on the stator side, to the brushes of the induction motor, which rest permanently on the sliprings, and on the slipring side, to the secondary winding of the current transformer Ti, as shown in the above diagram. The current of induction motor, stepped down in the transformer Ti, is used for the excitation of frequency changer, and led into the latter through the sliprings; the pressure thus produced between the commutator brushes is applied to the rotor circuit at the sliprings of the machine. As mentioned before, this EMF must have a given phase displacement in relation to the slip-EMF in the rotor circuit, in order to obtain the desired conditions; this phase displacement is permanently fixed by the relative position of the two rotors, which must be suitably chosen when coupling the machines.

Owing to the fact that the compensated frequency changer is series-excited, the excitation of this machine increases with the current of induction motor, and a variation of slip is produced, similar to that obtained by means of slip resistances; on the other hand, the phase of the counter-EMF of the frequency changer varies with the current of induction motor. It is therefore possible to arrange, without special device, that, when the slip increases, an over-compensation of motor takes place automatically up to high overloads. If the two rotors are suitably coupled together, the counter-EMF created in the frequency changer can be used nearly entirely for compensating the wattless component, when the induction motor is on no-load, only a very small component being taken for producing a slight over-synchronism of set. When the load increases, the induction motor absorbs watt-current, and the resulting additional excitation of frequency changer is mainly an EMF producing a slip, and only a small component causes further supply of wattless current to the system.

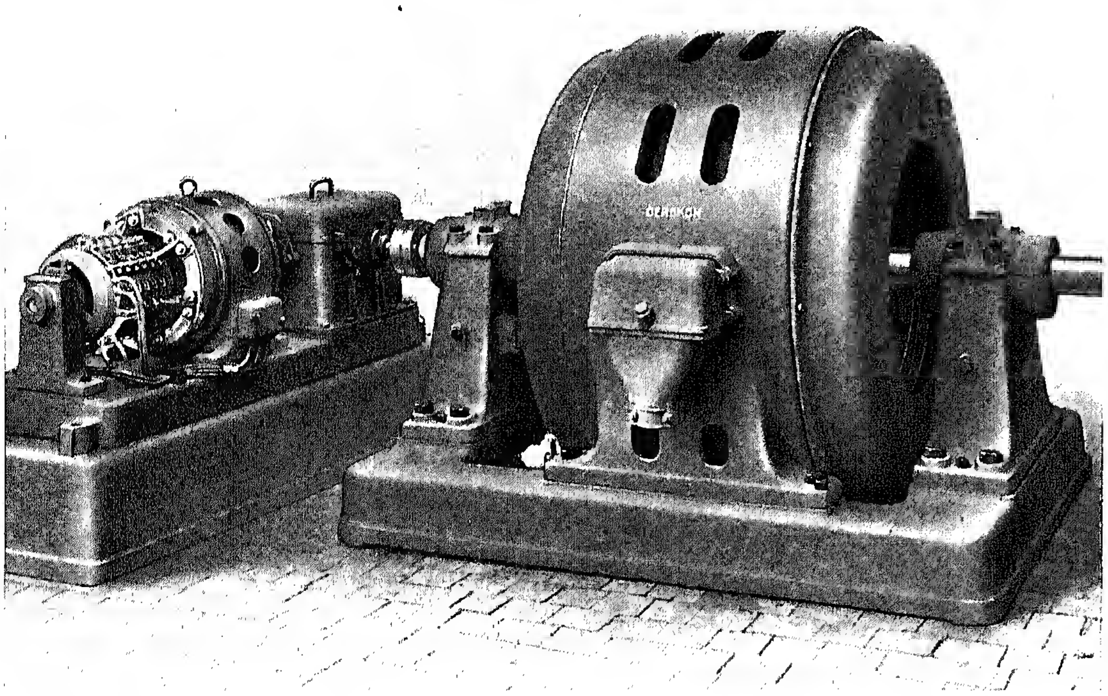


Fig. 2. Motor equipment for 350 HP, 370 r.p.m., 3000 volts, with phase compensator.

The curves in Fig. 1 show the type of characteristics obtainable with induction motors provided with such series-excited compensated frequency changers; for the purpose of comparison, data are also given for the induction motor alone. The current taken from system, as well as the power factor and slip are plotted in function of the energy drawn from the system at various loads. The supply pressure was maintained at 3000 volts within a few percents. As can be seen, the speed characteristics of set are quite similar to those obtained in the case of slip regulation by means of resistances. On the other hand, a high compensation of wattless KVA is attained, wattless current being supplied to the system, both within the normal range of operation and up to high overloads. In view of this, the overload capacity of set is a multiple of that of non-compensated induction motors.

The Question of Safety of Large Turbo-Generators. (Continued from page 303).

Apart from the safety of rotor body, from a mechanical point of view, the ability of the stator winding to withstand short-circuits is of the utmost importance. Although the breakdown of a stator winding is generally far from having as serious results as, in certain cases, the explosion of a rotor, the rewinding or careful repair of a stator damaged by a short-circuit is a lengthy and expensive matter. In the case of a sudden short-circuit, however, it is not only the stator winding that is endangered, but the coupling and bearings are also subjected to very heavy stresses, specially with single-phase short-circuits, which have to be taken into account*). It may be pointed out that the term "security against short-circuits" is meant to cover the absolute immobility of the whole winding in the event of a sudden short-circuit, that is to say, absence of all displacement of its various parts; the latter condition is a matter of the utmost importance as the repetition of such displacements may lead to breaks or gradual damage to the insulation, so that punctures are then liable to occur and the winding becomes defective. Over 500 sudden short-circuits were carried out on a standard 2500 KVA turbo-generator, in order to obtain the necessary data for dealing with the forces that come into play under such conditions**).

The illustration on the following page shows the method adopted to support the stator winding of a 23 400 KVA generator, for the purpose of rendering it secure against short-circuit stresses. In this connection, it may be said that designs of winding supports are often encountered where the ends of windings are nearly entirely covered by a mass of clamps and bolts; this abundance of supports, while in no way increasing the security against short-circuits, unless each support is specially adapted to the magnitude and direction of the force to be dealt with, necessarily interferes very materi-

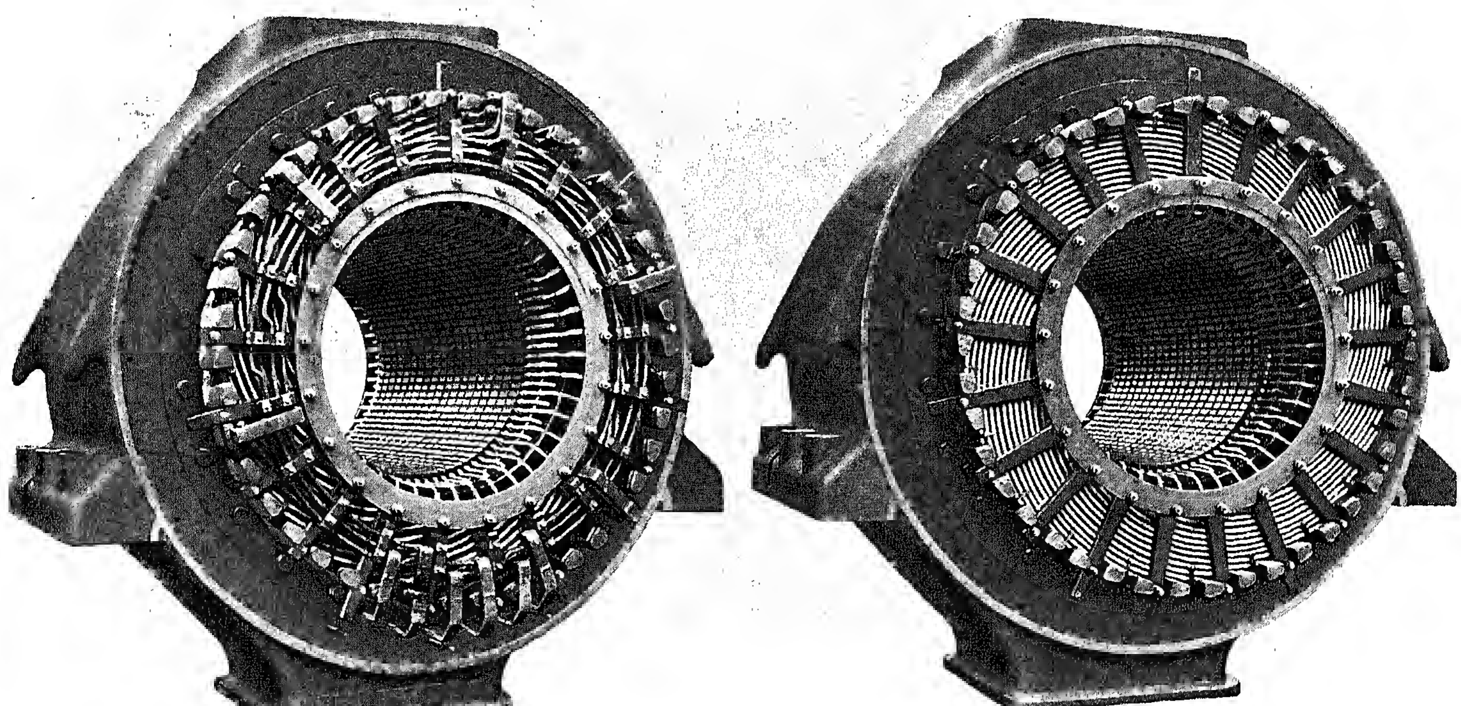
*) See also "Experimental investigations regarding sudden short-circuits in A. C. generators" by H. Rikli, in the "Bulletin de l'Association Suisse des Electriciens" No. 5, 1925.

**) See also "Measures adopted for dealing with short-circuit stresses in stator windings of turbo-generators" in Bulletin Oerlikon No. 28 of October 1923.

ally with the ventilation of the ends of coils. It is, above all, important to link up the supporting structure of winding with the stator casing, in order to prevent an angular displacement from taking place, as the enormous braking forces which come into play in the event of a sudden short-circuit do not only act between the core of rotor and stator, but are also partly applied to the ends of winding. This stiffening is ensured by the circular comb which clamps the coils along the whole periphery, as they leave the slots, and are themselves secured to the end plates of stator; the rest of the supporting structure is likewise linked up with the sides of the casing. Both supporting arrangements can be clearly seen in the illustration. The internal forces in the ends of coils themselves are relatively easy to deal with by providing a sufficient number of clamps and distance pieces.

to the method of testing with pressure impulses, the insulation between turns of such coils withstands a much greater pressure, — at least 1.5 times working pressure.

In order to be able to maintain the winding in good condition, it is not only necessary to pay the greatest attention to the question of design, but also to keep the interior of winding always sufficiently clean. This has led to the general adoption of air filters with turbo-generators, from an early date. It is, however, not possible to keep the windings permanently clean even by resorting to the best filters, as shown hereafter. Non-filtered air contains about 10 milligrams of dust per m^3; if it is passed through a filter having an efficiency of 95% — a very high figure — the air still contains after this process 0.5 milligrams of dust per m^3. A 30000 KVA turbo-generator requires for cooling purposes about 30 m^3



Views of stator of a turbo-generator for 23400 KVA, 3000 r.p.m., showing method of support adopted for rendering winding secure against short-circuit stresses.

The task of rendering the stator winding secure against breakdown of insulation, when the value of pressure is not very high, is a problem which has long been solved and does not present any difficulty, insofar as the measures adopted to protect the stator winding against short-circuit stresses ensure the preservation of insulation in good condition. A matter of greater importance is that of security against internal short-circuits, due to defects of insulation between turns, such as may occur in the case of high pressures and may often be the actual cause of breakdowns of windings. If the insulation is only provided for the normal pressure between turns during service, it is insufficient, as surges due to switching operations or other causes, give rise to very high pressures, specially in the first coils. The insulation between turns of Oerlikon generators is always sufficient to withstand the full working pressure up to 12000 volts. In the case of turbo-generators, where the winding consists of half coils, this insulation test with full working pressure is carried out on all coils in the ordinary course of manufacture. When resorting

(1059 cu. ft.) of air per second. It follows that during a total yearly period of service of 5000 hours the quantity of dust that reaches the machine, in spite of the filter, amounts to $0.5 \times 10^{-6} \times 30 \times 60 \times 60 \times 5000 = 270$ kg (595 lbs), of which a good part remains in the blind corners; this causes the gradual clogging of fans and coating of windings with dirt. For this reason, use has been made, in recent times, of the closed circuit method, specially in the case of large units requiring great quantities of cooling air. With this mode of cooling, the same air flows continuously through the generators, the ducts being arranged so as to form a closed circuit. The air is then always cooled down to the permissible inlet temperature, in special coolers arranged outside the generator. We recommend the closed circuit method mainly in cases where the atmosphere is very dusty and the outputs are large, as it is only when using this mode of cooling that the generators can be kept clean.

The Oerlikon turbo-generators thus satisfy in every respect the most exacting requirements, in the matter of reliability, that can be laid down for modern generators.

BULLETIN OERLIKON

No. 75 — September 1927

Contents: Latest developments in the design of Oerlikon Steam Turbines.

This issue includes a sheet with Figs. 4 to 9.

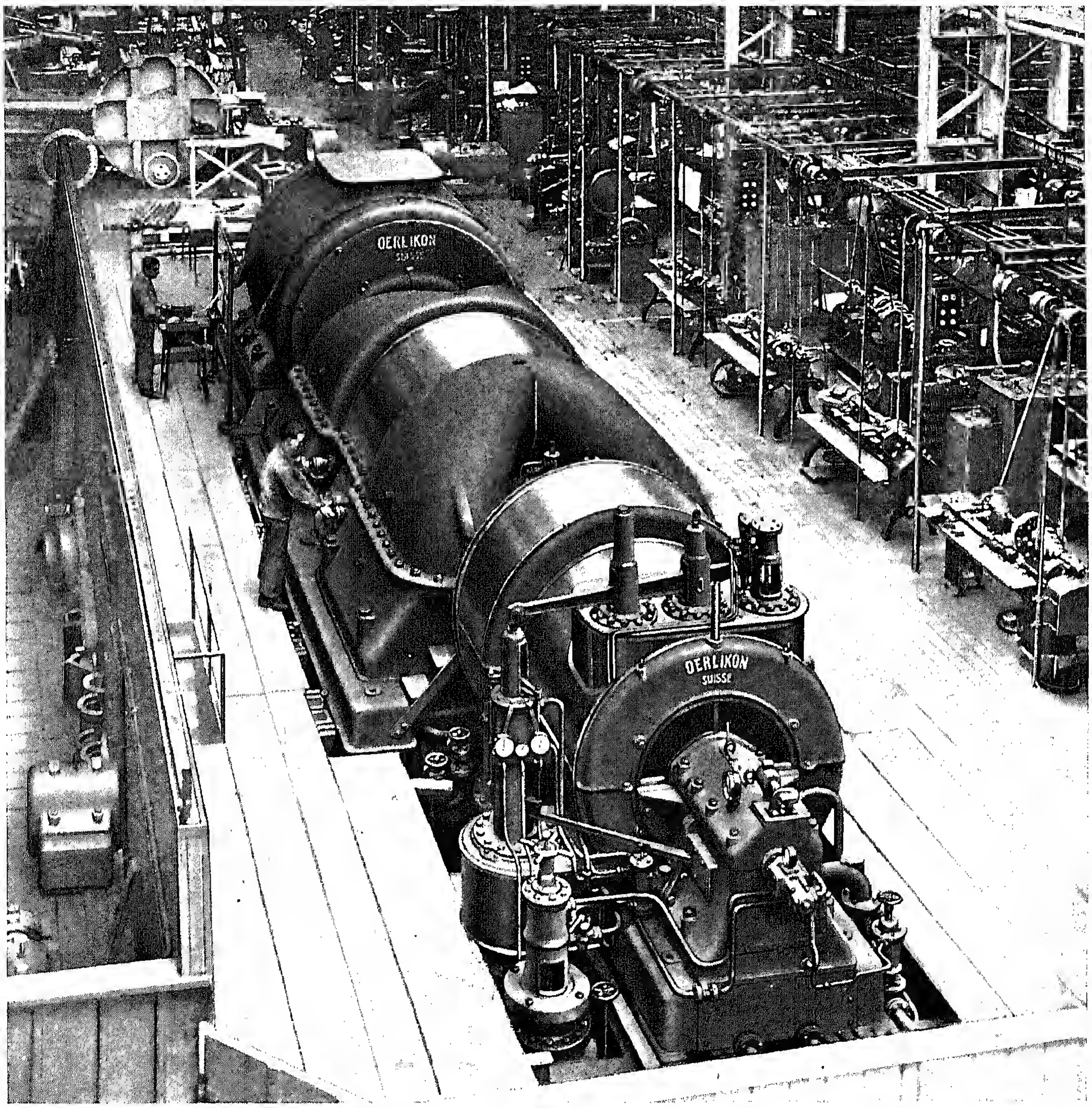


Fig. 1. 18750 KW Turbo-generator for 3000 RPM, with two-flow turbine, on the test bed at the Oerlikon Works.

Latest Developments in the Design of Oerlikon Steam Turbines.

The points on which designers of steam turbines have been concentrating more and more, namely absolute reliability in operation and, at the same time, highest possible efficiency, have always been foremost considerations when designing Oerlikon turbines. Great efforts have been made, in particular, in recent years, with a view to reducing the heat consumption of turbines, on account of the rise in price of coal following the war, and of the enormous increase in capacity of units, while the knowledge that the thermal efficiency of plant could still be considerably improved has given a great impetus to the matter. The means of attaining the object in question are to be sought in first place in the improvement

of the efficiency of the turbine itself, secondly in the increase of the heat drop available for turbine by raising the steam pressure and temperature, and thirdly in the improvement of the heat process by regenerative arrangements and intermediate re-heating of steam.

It may be of interest to mention that the Oerlikon Company obtained, with their turbines, efficiencies of 75% and more, as far back as 1913 (see Journal of the Association of German Engineers, page 1698, etc.); since then, the efficiencies have been greatly increased and reach, at the present day, values above 80%. The efficiency of turbine depends upon a number of factors; it is dependent in first place upon the construction of machine and, further, upon the section of blades, spacing of blades, axial play, distribution of the heat drop, number of stages, etc. In order to ascertain the influence of these individual factors, the Oerlikon Company have made exhaustive tests, which have enabled them to carry out such improvements in turbine design as were still possible. Some of these improvements have been made in recent years, and in question cannot be used efficiently in one stage, owing to the high vacuum, the stream of steam is divided in two or three parts. This has led to the construction of two and three-flow turbines which are provided with casing in two or more sections according to the initial pressure. In view of this, it is possible for the Oerlikon Company to build, at the present time, turbines up to 40000 KW at 3000 rpm. and 150000 KW at 1500 rpm. with high efficiencies.

Fig. 2 shows a 4000 KW Oerlikon turbine at 3000 rpm. and Fig. 3 a 10000 KW turbine which, in spite of the high vacuum, has still a casing in one part. The illustration on the front page represents an 18750 KW two-flow turbine at 3000 rpm. on the test bed. These turbines differ outwardly from former designs mainly in that the governor is arranged inside the pedestal of the high pressure bearing.

The Oerlikon Company have always used pressure stages only, even in the high pressure part, in the case of units for average and large outputs, and dispensed with a velocity stage wheel. The advantage of velocity stage wheels of permitting of

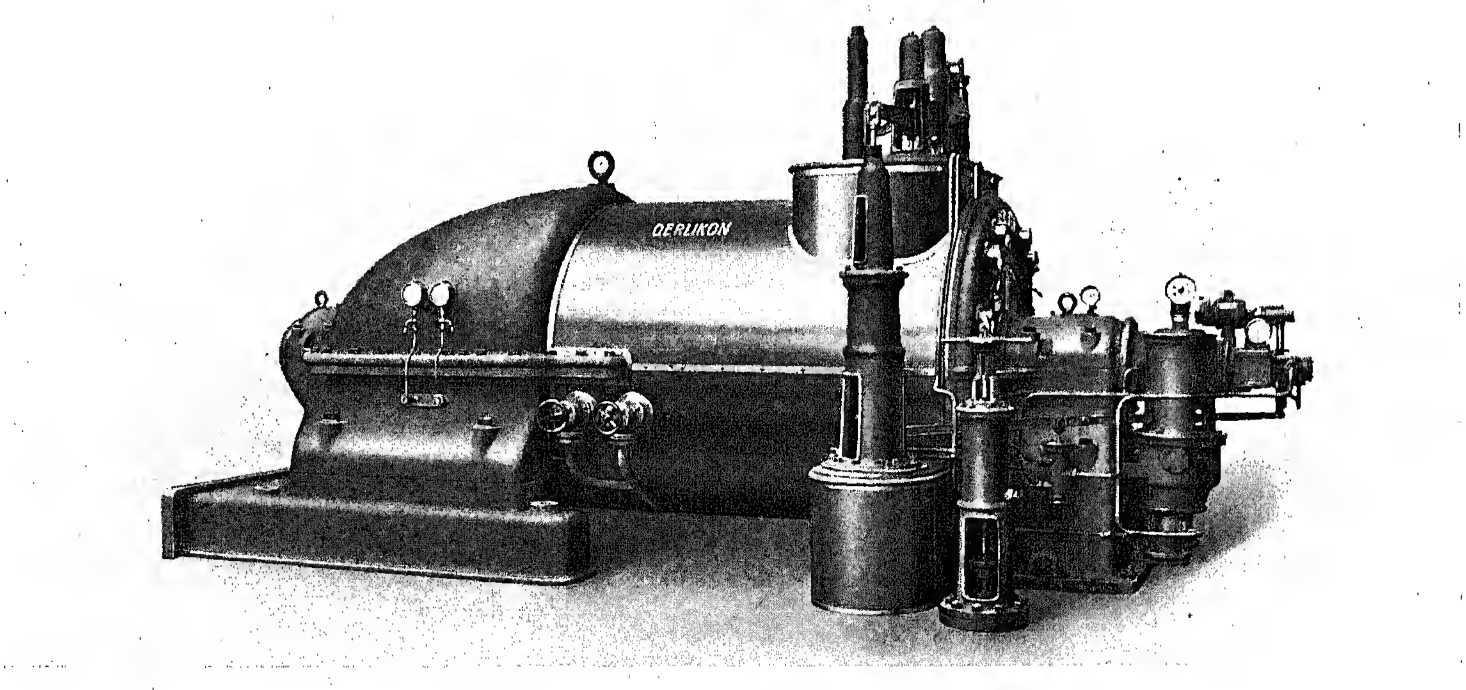


Fig. 2. 4000 KW Oerlikon Turbine for 3000 RPM.

the efficiencies obtained are, at the present day, amongst the highest attained.

No essential alterations have been made to the plant. The Oerlikon turbine is still now an impulse turbine with, as a rule, partial admission in the high pressure part, and full admission in the low pressure portion. The number of stages varies with the heat drop and speed. For normal steam conditions (pressures up to 285 lbs/sq. in.), the Oerlikon Company used to provide 16 to 20 stages at 1500 rpm., and 10 to 13 stages at 3000 rpm. At the present day, the number of stages at 3000 rpm. has been increased to 12 to 16, the diameter of high pressure part being chosen considerably smaller than that of the low pressure portion, in the case of large units. When the steam pressure exceeds a certain value (about 355 lbs/sq. in.), the turbines are built with casing in two sections, from average capacities upwards. The runners of the high pressure part are then designed with a smaller diameter and the corresponding casing is made of special cast steel. In the case of high capacities (12000 KW and more) where the large quantities of steam operation even at overloads, at the same high efficiency as at full load, is secured here through the adoption of the new Oerlikon method of admitting steam for pressure stages. Fig. 4 (see attached sheet) shows the old method of introducing the steam, and Fig. 5 the new arrangement (Swiss Patent 82314). Formerly, the additional steam was admitted after the high pressure wheels, so that the steam did not produce any work in the high pressure part. With the new design, however, the additional steam is also led into the first stage and, after flowing through it, passes into the third stage. Under normal conditions, the channels in question are closed by valves, so that no additional steam is admitted (see Bulletin No. 4, 1921). As soon as the turbine is overloaded or the normal quantity of steam is insufficient for developing the desired output, the auxiliary valves open and permit of the passage of additional steam through the first and third stage where it produces work. It may be pointed out that the heat drop in the high pressure part is smaller during overload than during normal load, as the pressure in the intermediate chamber after the high pres-

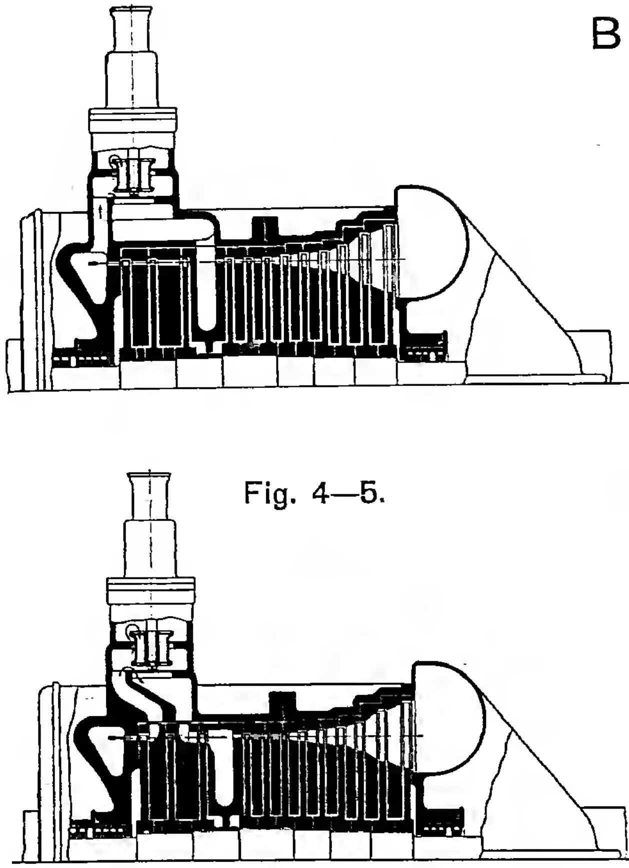
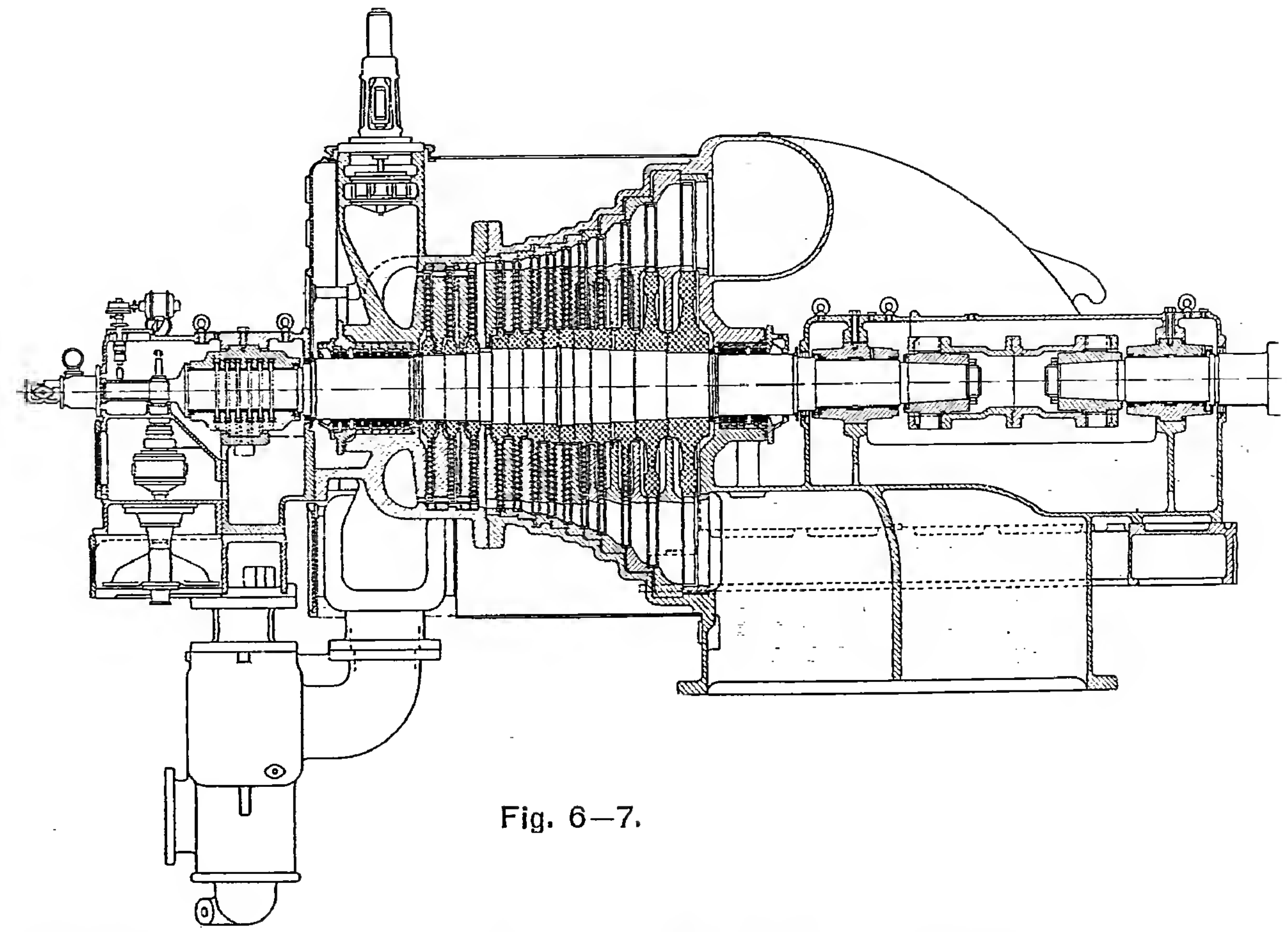


Fig. 4—5.



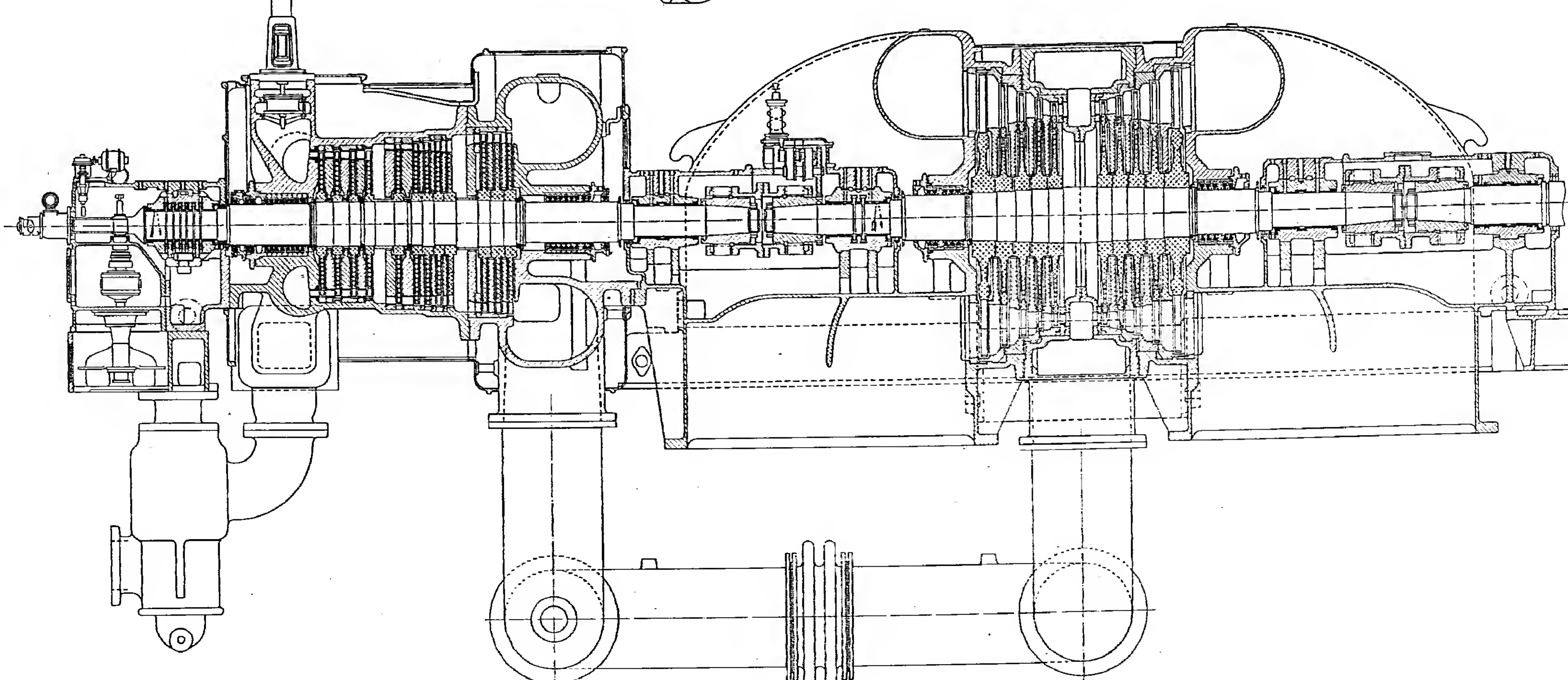


Fig. 6—7.

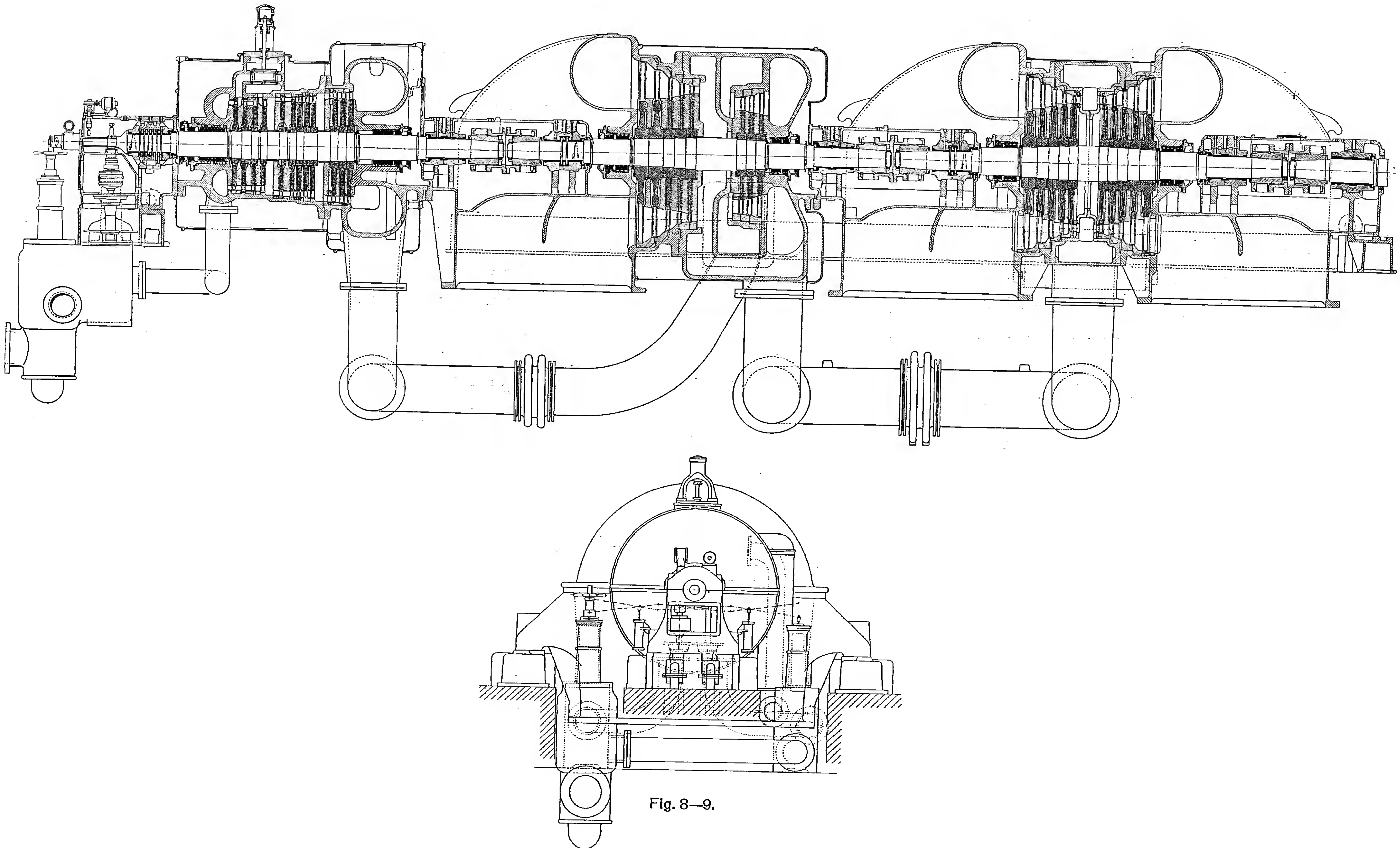


Fig. 8—9.

sure wheels increases as a result of the larger volume of steam; consequently, the heat drop of high pressure steam can be utilised advantageously in two stages. This explains the high efficiencies obtained with Oerlikon turbines, even at high overloads.

As regards the design of Oerlikon turbines, it has remained unaltered in its general lines, as stated before. The shaft is of Siemens-Martin steel and very amply dimensioned; it is carried in two bearings, the high pressure bearing being built as a thrust bearing. The runners are pressed on to the shaft, so that no loosening is possible during service. The emergency governor serving to prevent the plant from reaching excessive speeds, is mounted directly on the shaft. This emergency governor also comes into play immediately, in the event of an axial displacement of rotor of 1 mm (.04 inch) in the direction of steam flow; it thus removes effectively the danger of the inner parts of turbine being destroyed, as might otherwise be the case, in the event of the lining of thrust bearing melting, owing to a failure of oil pressure, etc.

present day requirements as regards reliability and high efficiency. Fig. 6 (see attached sheet) is a section through a 10000 KW turbine with casing in one piece, Fig. 7 a section through a two-flow 20000 KW turbine und Fig. 8 a section through a 30000 to 40000 KW three-flow turbine, the speed being in every case 3000 rpm. The steam flows first through the high pressure part where the stages have a small diameter, and then passes into the medium pressure portion. In the low pressure part, the steam flow is divided into three streams (see Specification of Swiss Patent 70675, 1915), which are led through different low-pressure sections. One of the low pressure sections is arranged in the same casing as the medium pressure part, while the other two are in a third casing. The turbine can be provided with 1, 2 or 3 condensers. Fig. 9 is a section through the governor gear. Two steam inlets are provided, with two stop valves and two throttle valves; there are also two overload valves, the second overload valve alone being mounted on the high pressure casing. The governor gear acts in such a way that, once the channels for normal steam supply are fully open, the

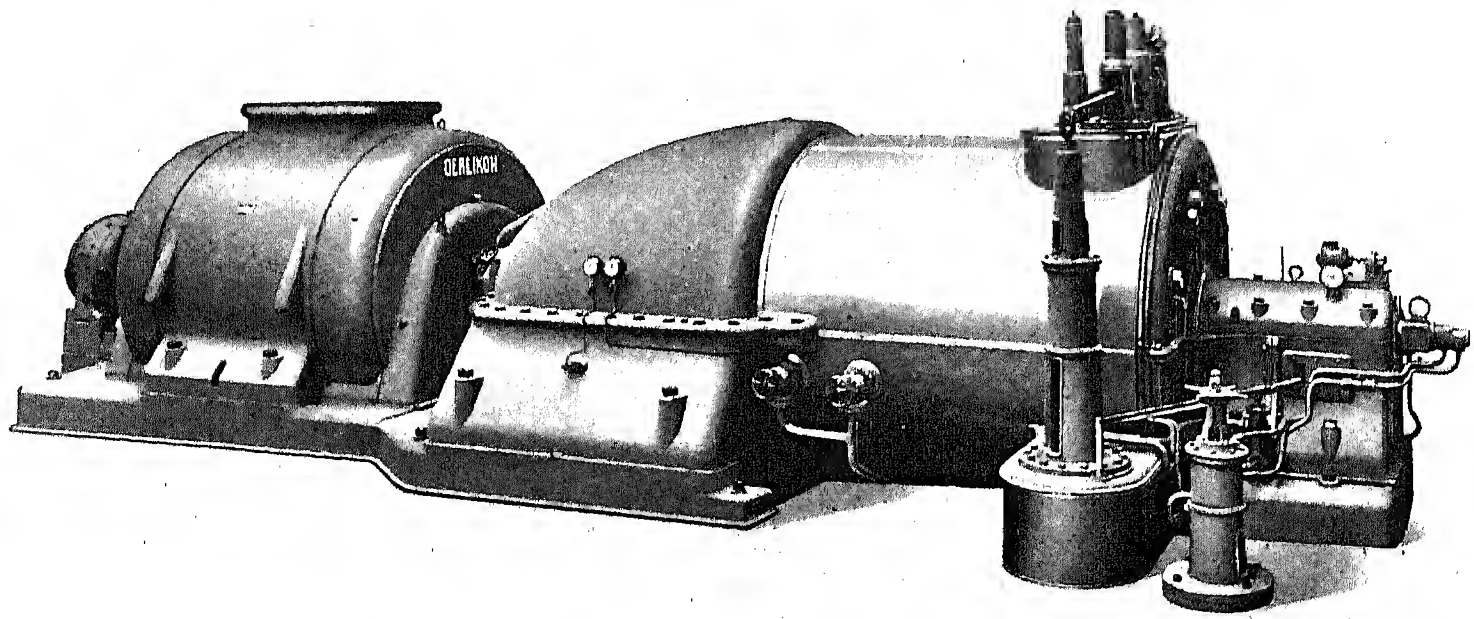


Fig. 3. 10000 KW Oerlikon turbo-generator for 3000 RPM.

The Oerlikon turbines are, as a rule, arranged with partial admission in the high pressure part; the diaphragms are then of wrought iron, and the guide blades are arranged in two or four groups, in boxes. In the part of turbine with full admission, the blades are cast into cast iron diaphragms. Guide blades, as well as runner blades, are made of stainless steel, in order to prevent rusting, although such blades cost twice as much as ordinary nickel steel blades. The runners and blades are so dimensioned as to ensure freedom from vibrations, the design evolved being based on exhaustive tests (see Bulletins Nos. 46/47). It may further be mentioned that, even with earlier designs, no accidents ever occurred to Oerlikon turbines, as a result of vibration of blades or runners. The Oerlikon Company have always adopted a higher degree of safety than is usual, when dimensioning the individual parts of turbines (3.5 factor of safety referred to yield point), and still adhere to this practice; this entails, it is true, larger dimensions and higher costs, but ensures absolute security. The Oerlikon Company are thus in a position to meet, with their turbine plant all the

second overload valve opens completely and the first overload valve throttles the steam supply through the additional channels to the first stage, until full overload of turbine is reached.

The output of turbine is usually regulated up to normal load by throttling the steam. Tests on different machines have shown that the gain secured by cutting out individual nozzle boxes, at half load, only amounted to 1—2 %; consequently, partial load valves are only provided now when the turbine has to work for long periods at partial load.

Tables I to IV give data regarding efficiencies obtained with Oerlikon turbines, all the machines in question being arranged for the new method of admitting additional steam. The figures are taken from the official tests.

The new method of admitting steam can also be used for improving the steam consumption at partial load. In this case, the turbine is calculated for a smaller output, 80 % of normal load, for instance; additional live steam is then introduced through the steam channels which would otherwise only be used for overload. Fig. 3 shows such a design. The arrange-

ment in question is mainly resorted to when the machines have to work for long periods at partial load or are for stand-by purposes.

Table I) Acceptance tests of a 1500 kW Oerlikon turbo-generator at the power station of the Compagnie de Floreffe, March 1926.

Load	5/4	1/1	3/4	1/2
Steam pressure in front of the turbine, in lbs per sq. in. (gauge)	179.2	195.5	200.2	200.7
Temperature in front of the turbine, in °F.	581.0	563.7	573.8	547.8
Vacuum at outlet of turbine, in ins. Merc.	27.39	28.45	28.54	28.79
Output, in kW	1753	1463	1158	752
Steam consumption per kW-hour, in lbs.	12.78	12.21	12.54	13.79
Efficiency of generator, in %	95.6	95.4	94.8	93 5
Efficiency of turbine, in %	75.8	74.6	71.6	65.5

Table II) Acceptance tests of a 5000 kW Oerlikon turbo-generator at the power station of the City of London Electric Lighting Company, September 1926.

Load	5/4	1/1	3/4	1/2
Steam pressure in front of the turbine, in lbs per sq. in. (gauge)	236.4	242.8	244.9	248.2
Temperature in front of the turbine, in °F.	586.4	559.4	527.0	505.4
Vacuum at outlet of turbine, in ins. Merc.	28.41	28.60	28.76	28.77
Output, in kW	6390	4850	3715	2535
Steam consumption per kW-hour, in lbs.	11.29	11.48	12.23	12.80
Efficiency of generator, in %	95.9	95.5	94.7	92.8
Efficiency of turbine, in %	77.4	76.1	72.3	71.3

Table III) Acceptance tests of a 6000 kW Oerlikon turbo-generator at the power station of the City of York Electric Lighting Department, February 1926.

Load		5/6	2/3	1/2
Steam pressure ¹) in front of the turbine, lbs./sq. in. (gauge)		157.6	155.6	156.9
Temperature in front of the turbine, in °F.		521.2	525.7	521.4
Steam pressure ²) in front of the first diaphragm, in lbs./sq. in. (gauge)		151.9	127.0	91.7
Vacuum at outlet of turbine, in ins. Merc.		28.99	29.15	29.16
Output, in kW		5140	4260	3025
Steam consumption per kW-hour, in lbs.		11.30	11.36	11.94
Power factor		0.895	0.846	0.794
Efficiency ³) measured at terminals of generator	in %	76.5	74.7	70.8
Efficiency of generator	in %	95.0	94.7	93.8
Efficiency of turbine referred to ¹)	in %	80.5	79	75.5
Efficiency of turbine referred to ²)	in %	81	80.5	81.0

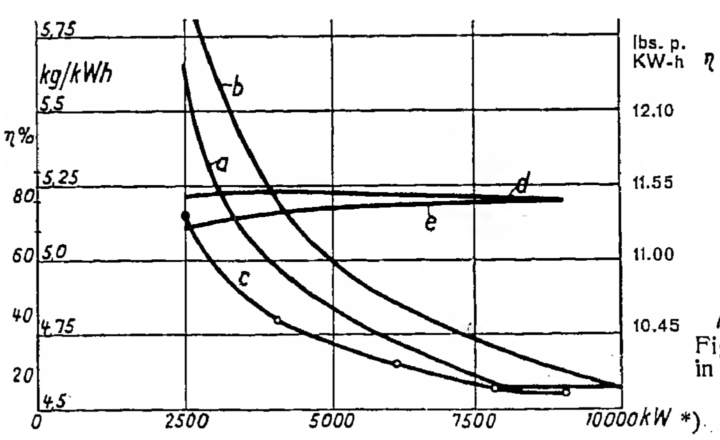
In 1926, a 10000 KW set of this description was supplied to the Saarlouis Power and Traction Company. As the turbine was only to be used at low loads — 2500 to 5000 KW — during the first years, it had to be arranged that the plant should work satisfactorily at partial load. For this purpose the turbine was designed so as to have its best steam consumption at 8000 KW. The guarantee figures are given under *a* in Fig. 10. As can be seen, an equally good steam consumption was guaranteed for 8000 KW and 10000 KW. If this machine, which is built with casing in one piece, had been normally designed for 10000 KW, it would hardly have been possible to give a better guarantee figure for 10000 KW, owing to the high vacuum. In the case of partial loads such as had to be dealt with during the first years, the values would have been considerably more unfavourable (Curve *b*), and this to the extent of 5 % at 1/4 load. The acceptance tests took place on the 10/11th February, 1927. Owing to the low temperature of river water, the vacuum produced by the condenser was considerably higher than provided for and could not be used efficiently at high loads, as can be seen from the efficiency curves of turbine, referred to the conditions in front of the first diaphragm (Curve *d*). The values obtained at the acceptance tests are contained in Table IV.

Table IV) Acceptance tests of a 10000 kW Oerlikon turbo-generator of the Saarlouis Power and Traction Company, February 1927.

Load, in %	90	80	60	40	25
Steam pressure ¹) in front of turbine, in lbs./sq. in. (gauge)	185.8	211.1	201.7	205.4	203.6
Temperature in front of turbine, in °F.	657.1	662.0	642.7	647.6	631.9
Steam pressure ²) in front of the first diaphragm, in lbs./sq. in. (gauge)	183.1	181.9	142.8	95.2	61.0
Vacuum at outlet of turbine, in ins. Merc.	28.09	29.20	29.34	29.36	29.49
Steam consumption per kW-hour, in lbs.	10.21	10.02	10.40	10.68	11.64
Output, in kW	9067	7840	6128	4057	2505
Efficiency of generator, in %	95	94.8	93.5	91.4	89.1
Power factor	0.971	0.965	0.913	0.898	0.795
Efficiency of turbine referred to ¹), in %	79.5	78.7	78.1	75.7	70.8
Efficiency of turbine referred to ²), in %	79.7	80.2	81.5	82.8	81.1

The efficiencies referred to the conditions in front of the first diaphragm reach values in the neighbourhood of 80 % and more at all loads. The maximum efficiency was obtained for 4000 KW, as the high vacuum could still be used efficiently at that load. Curve *c*, in Fig. 10, gives the corrected steam consumption figures reduced to the conditions of contract. Curve *e* represents the efficiencies of turbines referred to ¹). It may be mentioned that the machine in question works so satisfactorily at partial load that it can deal with any load encountered during service.

In Fig. 11, comparative curves are plotted showing the improvements in turbine efficiencies secured during recent years. The values represented by curve 1926 are those given in Table III under ³) and measured at the terminals of generator. The curve 1925 represents the efficiencies of a 3500 KW set taken in 1925 (see The Engineer of 11th June, 1926). As can be seen, the efficiencies of 1926, for the same load, are up to 10 % higher than those of 1925; this improvement is mainly due to the turbine. Fig. 12 (Bulletin No. 54) shows the improvement in steam consumption and efficiency obtained in the case of two turbines installed in 1925 at the Wood Lane power station of the Kensington and Notting Hill Electric Lighting Companies to replace machines supplied in 1908. The increase in efficiency of turbines amounts to about 25 % of the 1908 value.



*) Generator output.

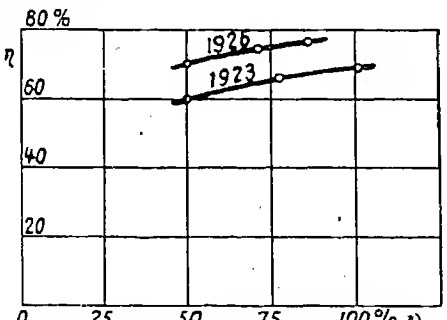


Fig. 11. Efficiencies of a 3500 KW set in 1923, and of a 6000 KW set in 1926.

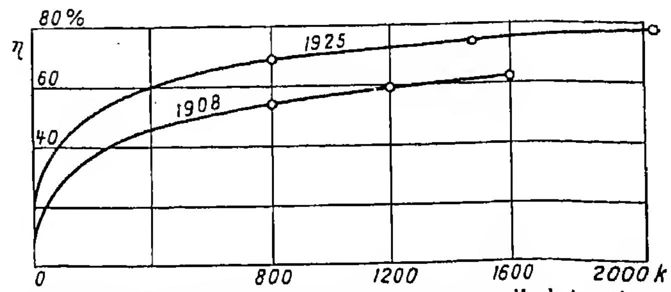


Fig. 12. Efficiencies of the sets supplied to the Kensington and Notting Hill Electric Lighting Companies.

Fig. 10. Steam consumption and turbine efficiencies of a 10000 KW set.
a) Guaranteed steam consumption. b) Guaranteed steam consumption for a turbine normally designed for 10000 KW. c) Measured steam consumption. d) Efficiency referred to the conditions in front of the first diaphragm. e) Efficiency in front of the turbine.

BULLETIN OERLIKON

No. 76 — October 1927

Contents:

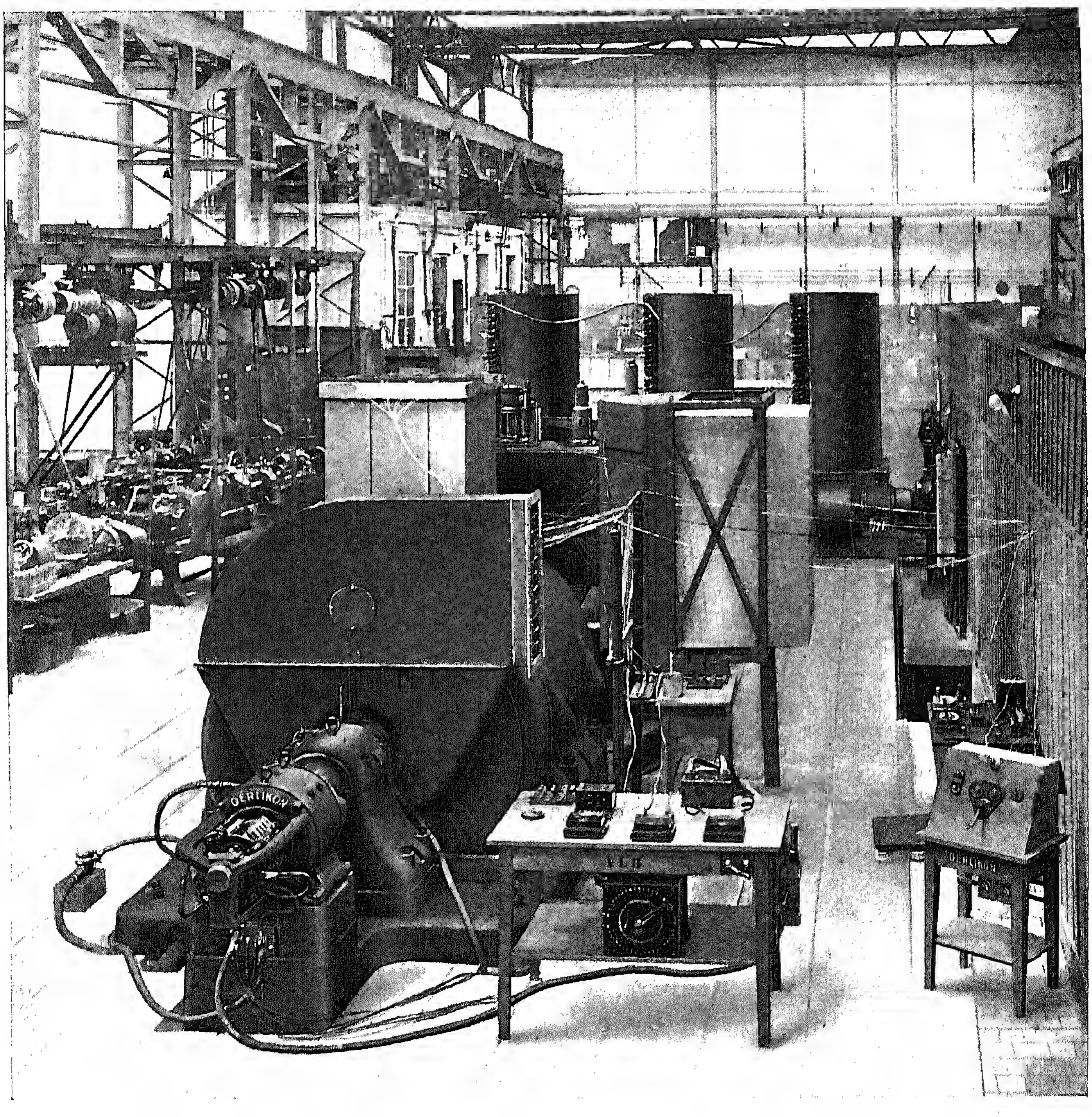


Fig. 1. Determination of efficiency and measurement of temperature of a turbo-generator at full load and power factor = o up to 40000 kVA.

Efficiency Guarantees and Determination of Efficiency of Oerlikon Turbo-Generators.

The Oerlikon Company are now in a position to determine the actual efficiency of generators very accurately, as they have built large loading reactances which permit of the testing of plant up to a capacity of 40000 kVA, under full load conditions at power factor zero. These tests have shown that the efficiencies calculated on the basis of light load and short-circuit losses, in the ordinary way, were always lower in value than the actual efficiencies. This must be ascribed to the fact that the so-called eddy current losses to which the stator current gives rise are, in part, much higher under

short-circuit conditions, i. e. when there is no main field, than with the generator normally excited and same value of current. It has been established as a result of exhaustive tests carried out under short-circuit and full load conditions, that the stator leakage field upon which these eddy current losses depend does not assume so large a value at full load, i. e. with the generator fully excited, as during short-circuit; this is due to the fact that when the machine is excited, the magnetic portions of the leakage path are already saturated by the main field or by the leakage field of the latter, so that the resistance encountered by the stator leakage field is far greater than during short-circuit, when there is no main field to saturate these parts. The difference between the value of efficiency determined in the ordinary way, and the actual efficiency can amount in certain cases to .2—.5 % and more; this depends upon the relative value of eddy current losses. The Oerlikon Company have been successful in reducing the losses from this source to quite moderate values, in turbo-generators, in spite of the fact that this type of plant is noted for high eddy current losses; this result has been achieved by devoting the greatest attention to the question of design and by making use, in this connection, of the valuable data collected during exhaustive tests. In view of this, the differences between the values of efficiency determined in the ordinary way and the actual efficiencies are not very great and should, in general, be less than .5 %. As the Oerlikon Company, however, have the means of determining the actual efficiency very accurately, they have kept to the method of determining the actual efficiency by loading tests at power factor = o. The procedure, in this connection, is as follows:—

In view of the fact that the loading reactances are designed so as to permit of different ways of connecting up, and are provided with a number of tappings, the load can be adjusted within the closest limits at power factor = o and normal pressure, in the case of all current conditions. The energy carried away by the air streaming through the machine is then measured during continuous operation with the plant working on load at power factor = o.

When doing so, it is, above all, necessary to ensure stable conditions. The machine must have practically reached its final temperature, so that no more energy should be diverted from the cooling air for heating up parts of the machine. On the other hand, precautions must be taken to ensure that the flow of air is as far as possible uniform and that the temperature of air remains constant, as a variation in temperature of cooling air, during the test, as a result of a change in temperature conditions between inlet and outlet, would impair the accuracy of the measurement of heating of air.

The following have to be determined:—

1) the amount of cooling air per second and its weight.
2) the rise in temperature of air as it passes through the generator.

The Oerlikon Company use, as a rule, for the determination of the quantity of cooling air, a calibrated anemometer. This method of measurement presents several advantages over that where a nozzle is utilised and the results obtained are as accurate as readings of a water column of a few mm. on a nozzle. The mode of measuring the flow of air by means of a nozzle is based on the assumption that the outlet velocity in the nozzle is perfectly uniform. Such conditions can only be obtained by taking certain precautions (by providing a settling chamber and a screen in front of the nozzle); this can, however, also affect, to a certain extent, the actual cooling conditions, and consequently, the light load losses depending on them. For the measurement of air by means of anemometer, an extension, with parallel walls, is mounted on the upper air outlet of generator; this extension is further provided with internal guide vanes perpendicular to each other, which ensure, as far as possible, a parallel and rectilinear flow of air. Even with these vanes, the outlet velocity is not uniform at the upper end of the extension. In view of this, the top opening is sub-divided into a number of sections equal in size and approximately square, by means of wire stretched across; the outlet velocity is then measured in each of these squares by means of the anemometer. Measurements are made successively in each section for a period of exactly five seconds and the sum of the readings is divided by the total number of seconds. For determining the specific weight, it is still necessary to measure the temperature of the escaping air and the barometric pressure.

The specific weight is given by the following formula:—

$\gamma = \frac{P}{R \times T}$, where P = barometric pressure in mm. water gauge, R = constant for gases = 29.27, T = absolute temperature.

The heating of air is measured electrically by means of thermo-couples. In this connection, use has been made for many years, of a very accurate method, whereby it is possible to obtain directly, by means of a single reading, the average value of the difference in temperature between inlet and outlet. For this purpose, thermo-couples are provided in each square and arranged in such a way that one joint is in a square of inlet opening and the other joint in a square of outlet opening. These thermo-couples (usually about 10 in number) are themselves connected in series as shown in Fig. 2. In this way, two advantages are secured. On the one hand, the deflection on the instrument is, in the case of 2×10 joints, 20 times greater than with individual readings; that is to say, the accuracy of reading is greater. On the other hand, the average value between the temperatures at both inlets and the outlet temperature is obtained by means of a single reading. By taking successive readings, it is easy to ascertain whether the final temperature of machine has been reached or whether the temperature of air is still rising. The illustration on the front page shows the arrangement of thermo-couples for the full load test of a turbo-generator; the loading reactances used in this connection can be seen in the background. The additional thermo-couples, which are also visible, serve for other purposes (study of local heating and losses). In order that the readings should not be affected by the long and numerous connections, the thermo-E. M. F. alone, without thermo-current, is measured by the compensation method.

The question of accurate determination of temperature by means of thermo-couples is dealt with, in a very exhaustive way, in the article on "Thermo-couples and their application in connection with the measurement of differences in temperature" by A. Schnetzler in the "Bulletin de l'Association Suisse des Electriciens" No. 11, 1925, where full particulars will be found regarding the matter. We only propose to give here the calibration curves used by us for copper-constantan thermo-couples. The curves in Fig. 3 show the correction to be made according to the temperature of the cold joint of thermo-couple, as it is a well-known fact that mea-

surements by means of thermo-couples are somewhat affected by the value of that temperature. The actual difference in temperature is thus given by the following expression:—

$$\Delta t\,^{0}C = \frac{E_{microvolts} \times 1000}{C_{t_2}}$$

When several thermo-couples are connected in series, as in the case of the present arrangement for the determination of the average difference in temperature of cooling air, the value obtained for E is to be divided by the number of thermo-couples in series. The energy carried away by the heated air is then given by the following expression:—

$$L_T = Q_L \times \gamma \times \Delta t \times c_p \times 4.189 \quad \text{in kW, where}$$

Q_L = quantity of air measured by means of the anemometer in cu. m./sec., γ = specific weight at outlet, c_p = specific heat of air at constant pressure = 0.238, 4.189 = electro-mechanical equivalent of heat. As $0.238 \times 4.189 = 1$, the expression assumes the simplified form: L_T in KW $= Q_L \times \gamma \times \Delta t$.

In addition to this, there is still the inherent energy of the escaping air at outlet due to its velocity v_{LA}; it is given by the expression below:—

$$L_v \text{ in kW} = \frac{Q_L \times \gamma \times v^2_{LA}}{2g} \times \frac{1}{102}, \text{where } 102\,\text{kgm/sec} = 1\,\text{kW}.$$

This amount is, however, usually very small (less than $^1/_2$% of the total energy measured) so that it can be neglected. There is also the heat radiation and heat dissipated by the casing. In order to cover this heat loss, an allowance is usually made of 8—10 watts per sq. m. surface of heated casing and 1° C difference in temperature between casing and air. The amount in question is, as a rule, about 1—1.5% of the total losses and can easily be calculated.

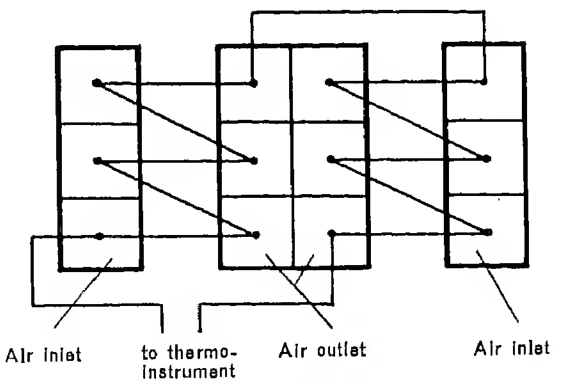


Fig. 2. Diagram of connections of thermo-couples.

It is further necessary to determine separately the losses due to bearing friction. The value of these losses can easily be derived from the quantity of oil and heating of the latter. The method outlined above for the measurement of losses is, of course, applicable for the determination of efficiencies at partial loads; it can also be used for measuring the losses when calculating the efficiencies in the ordinary way.

It is still necessary to deduct the following quantities from the losses at full load and power factor = o:—

1) Excess in excitation between full load at power factor = o and full load at the desired power factor. This amount can easily be calculated very accurately.

2) Excess in iron losses in stator laminations, owing to the internal E. M. F. being greater at full load and power factor = o, than at full load and the desired power factor. This value, which is of no great account, can also be determined with considerable accuracy once the internal reactance of generator and the iron losses have been measured at about normal pressure.

We are giving below two examples which show the difference in value between the efficiency obtained by the loading at power factor zero method and the ordinary method, respectively:—

1) Size 1264, 5200 KW, power factor = 0.8, 6500 kVA, 6500 volts, 3000 RPM.

Loading at P. F. = 0 method

6500 kVA, P. F. = 0 including radiation		322.0 kW
Bearing friction		24.0 „
		346.0 kW
Excitation, P.F. = 0	55 kW	
P. F. = 0.8	33 „	
	22 „	
Iron losses, P.F. = 0	100 kW	
P. F. = 0.8	92 „	
	8 kW	
	30	—30.0 kW
		316.0 kW

$\frac{5200}{5516} = 94.27\%$

Ordinary method

No-load (73+24 kW)	97 kW
Iron losses (6500 volts)	79 „
Short-circuit losses (577 amps.)	137 „
Excitation	33 „
	346 kW

$\frac{5200}{5546} = 93.75\%$

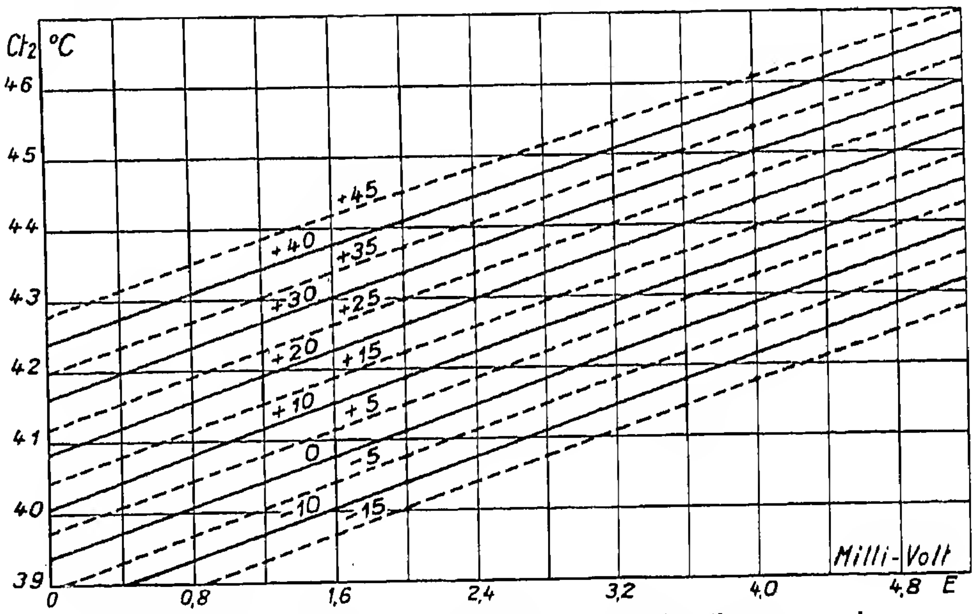


Fig. 3. Calibration curves of a copper-constantan thermo-couple.

2) Size 1296, 18750 kW, power factor = 0.8, 23 400 kVA, 6600 volts, 3000 RPM.

Loading at P. F. = 0 method

23400 kVA, P. F. = 0 including radiation		724.0 kW
Bearing friction		66.0 „
		790.0 „
Excitation, P.F. = 0	168 kW	
P. F. = 0.8	112 „	
	56 kW	
Iron losses, P.F. = 0	167 kW	
P. F. = 0.8	159 „	
	8 kW	
	64 .	—64.0 kW
		726.0 kW

$\frac{18750}{19476} = 96.27\%$

Ordinary method

No-load (214+66 kW)	280 kW
Iron losses (6600 volts)	144 „
Short-circuit losses (2050 amps.)	237 „
Excitation	112 „
	773 kW

$\frac{18750}{19523} = 96.03\%$

We guarantee the efficiencies, when determined by the loading at power factor zero method, with a tolerance of 10% of the total losses measured. When the efficiencies are calculated by the ordinary method, as laid down in our Continental Standards, the tolerances given in these Standards apply; the latter allow for a difference in efficiency of at least 1% for efficiencies above 90% and also for a tolerance of 10% of total losses measured, for efficiencies below 90%.

Notes and News Items.

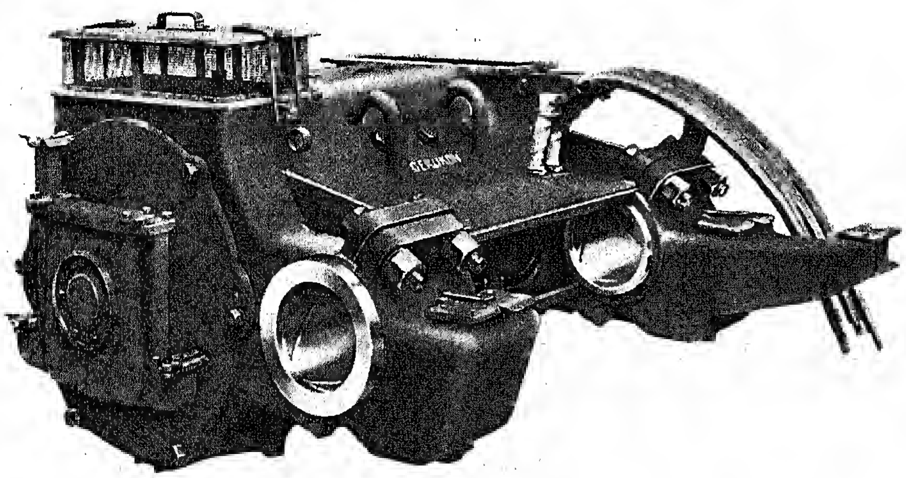
Traction motors for the 22 freight locomotives, type $C_0 C_0$, of the Spanish Northern Railway. In Bulletin No. 65 of November 1926, mention was made of the order received from the Cía. de los Caminos de Hierro del Norte, for 22 freight locomotives. We now propose to give a few details regarding the results of tests carried out on the motors (Figs. 1—2) of the first locomotives. All guarantees, such as could be checked at these tests, were found to be fully satisfied, while the conditions stipulated with regard to capacity of plant and commutation were considerably improved upon. The following are the figures laid down in the specification for the performance of motors at a pressure of 1350/3 volts, the conditions of operation being governed by the Rules of the A. I. E. E. (1925 Ed.).

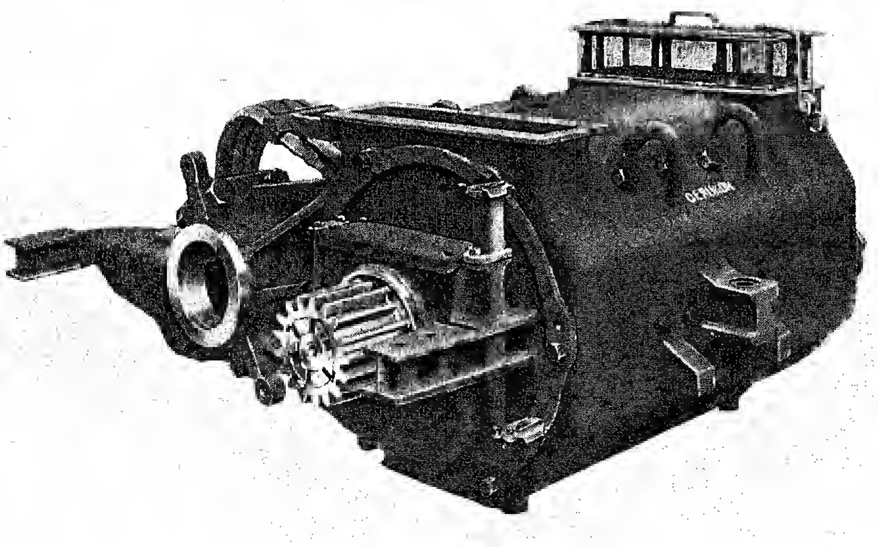
	Continuous rating	One-hour rating	
Output at wheel rim	**202 (275)**	**250 (340)**	KW (HP)
With full field and at a speed of	21.9	20.8	m.p.h.
Corresponding tractive effort	4620	6160	lbs.
Corresponding current	500	620	amps.
Maximum speed	56 m.p.h.		

The characteristics of motors given in Fig. 3 are based on measurements; they represent the average values obtained for the first 12 motors and coincide over their whole length with the calculated curves. Although a pressure of only 1350/3 volts was stipulated, tests were also carried out at 1350/2 volts, in view of the possible operation of motors at the latter pressure later on. The curves obtained for 1350/2 volts are plotted in Fig. 4. The values for continuous and one-hour rating, obtained from the heating tests are given below:—

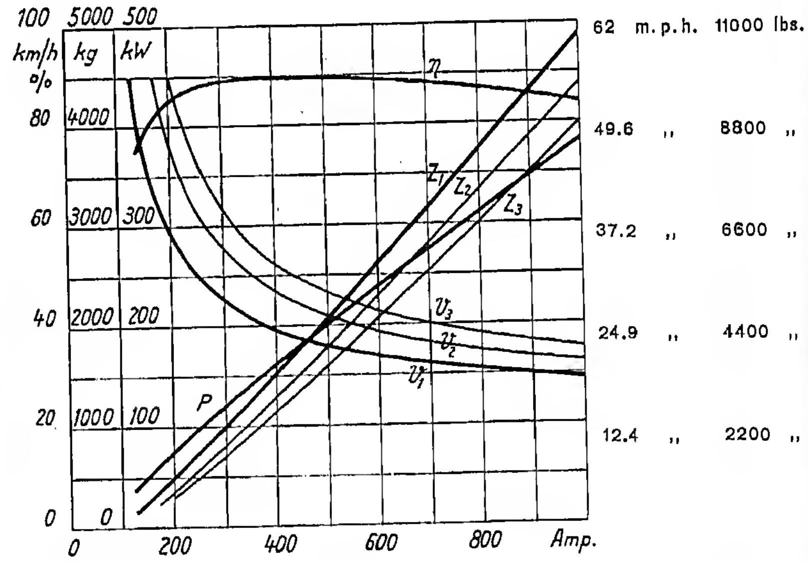
	Continuous rating		One-hour rating		
Pressure at motor terminals	1350/3	1350/2	1350/3	1350/2	volts
Current	545	480	715	580	amps.
Output at wheel rim	**220(300)**	**295(400)**	**280(380)**	**353(480)**	KW (HP)
With full field and at a speed of	21.1	33.5	19.6	31.6	m.p.h.
Tractive effort at wheel rim	5200	4400	7150	5590	lbs.

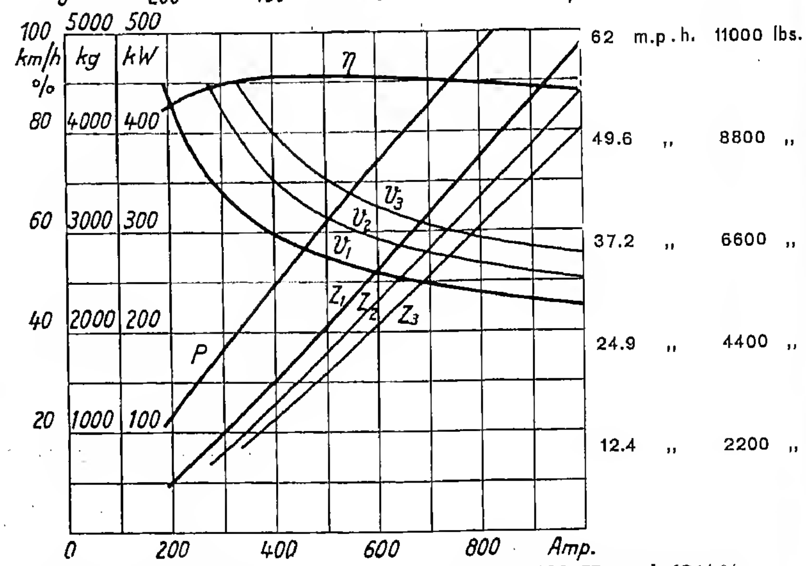
The conditions of operation laid down for the overload tests were 900 amps at 1350/3 volts with $62\,^1/_2\,\%$ field current, during 1 minute, with the motor warm. On the test bed, the motor was subjected continuously to a current of 900 amps at 1350/3 volts with $62\,^1/_2\,\%$ field current for 10 minutes, starting cold; during these trials, the heating only reached about 60% of the maximum permissible value. In order to test the commutation at increased pressure, the motor was run with a load of 370 amps. at 800 volts, i. e. at 1.8 times nominal pressure. Throughout all these tests, the commutation was entirely sparkless. Even when the current was raised to 1200 amps. at nominal pressure, there were no traces of sparking. The complete motor weighs 6720 lbs; this gives a weight of 30.3 lbs, and 22.7 lbs. per KW for the continuous rating, or 24 and 18.9 lbs. per KW for the one-hour rating. The corresponding weights per lb. tractive effort at the periphery of armature are 4.84 and 5.72 lbs., or 3.52 and 4.4 lbs. Considering the fact that motors for "tram suspension" have to be of very substantial construction, it will be seen from the above figures how advantageously these machines have been dimensioned and to what a degree every part has been utilised.





Figs. 1—2. Views of traction motor of the Norte locomotives, without gears.





v_1, v_2, v_3 = Speed, in m.p.h. } for 100, 75 and $62\,^1/_2\,\%$
Z_1, Z_2, Z_3 = Tractive effort at wheel rim, in lbs. } excitation, respectively.
η = Overall efficiency (motor and gears), in %.
P = Motor output at wheel rim, in KW.

Figs. 3—4. Measured characteristics at 1350/3 and 1350/2 volts per motor, respectively.

BULLETIN OERLIKON

No. 77 — November 1927

Contents: The new traction motors for the single-phase express locomotives with individual drive of the Swiss Federal Railways. — On the arrangement of main brake on winders. Notes and News Items. New order for locomotives for Spain.

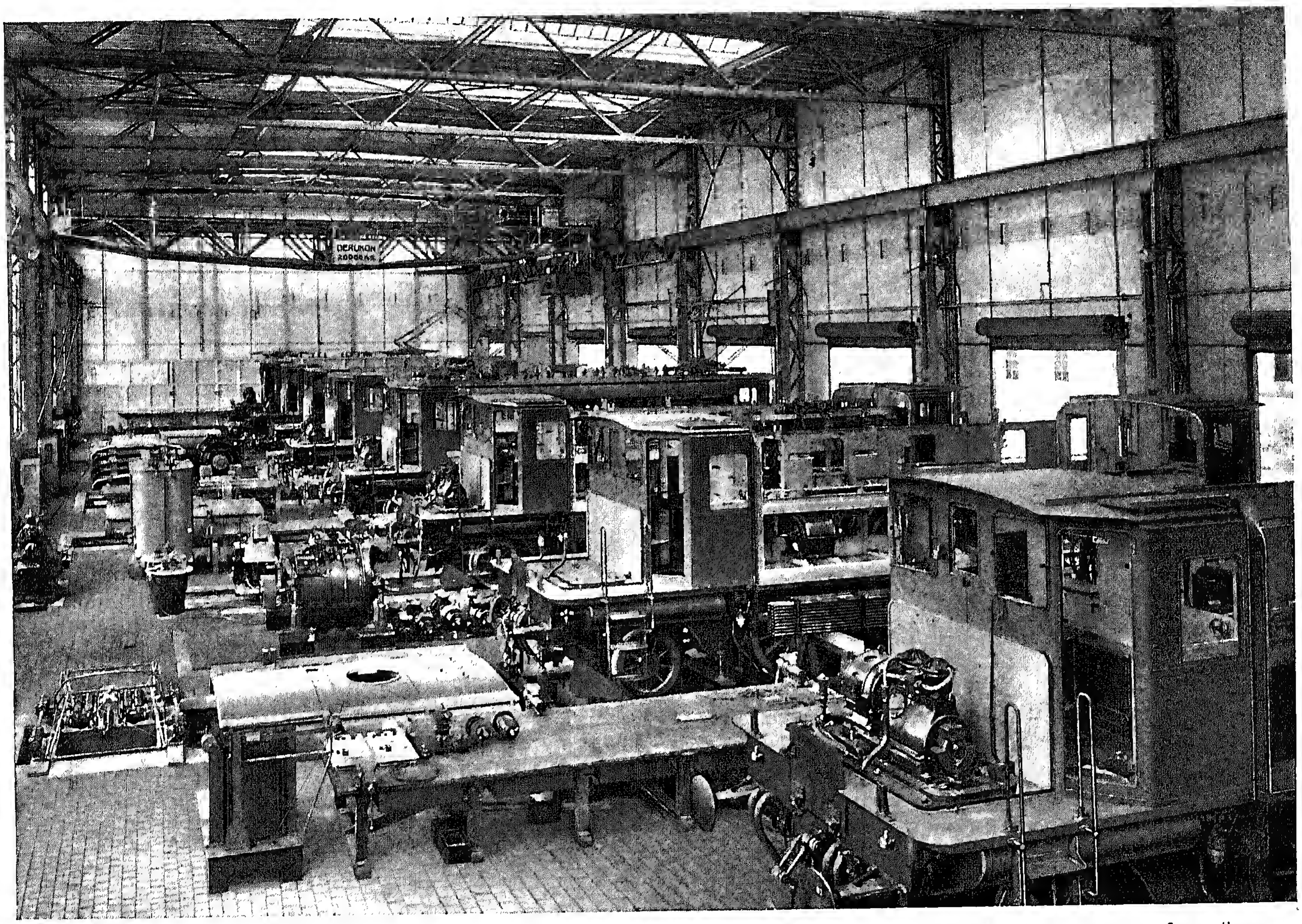


Fig. 1. Erection shops of the Oerlikon Company with locomotives for the Swiss Federal Railways in the course of erection.

The New Traction Motors for the Single-phase Express Locomotives with Individual Drive of the Swiss Federal Railways.

The express locomotives now being supplied by the Oerlikon Company to the Swiss Federal Railways (see also Fig. 1) are fitted with a new type of motor which had to be evolved to meet the special conditions imposed for the equipments in question. The task of designing these motors was in no way an easy one, as these machines had not only to be suitable for mounting on the standardised locomotive frames and to be interchangeable with existing motors, but had also to have, as far as possible, the same characteristics with regard to speed, current and tractive effort and at least as large an output as these machines.

The motors had to be guaranteed for a one-hour rating of 545 KW at 550 RPM and 380 volts, and for a continuous rating of 480 KW at 560 RPM and 370 volts. When designing the new motors, use was made of the same theoretical and constructional data as in the case of the last series of single-phase equipments on the freight locomotives type $Ce^{6}/_{8}$ *), for instance. In view of the excellent performance of the latter plant, there was every reason to hope that equally good results would be obtained with the new machines.

These expectations have been entirely fulfilled, and the tests have shown that the many requirements were fully

*) See Oerlikon Bulletin of January 1925, September/October 1926 and March 1927.

satisfied. The chart in Fig. 2 permits of the comparison of calculated and measured speeds for 190 and 380 volts. Fig. 3 is the vector diagram of pressures and currents of transformer and motor, based on the results of tests for the one-hour rating. It has been possible, by increasing artificially the inductivity of stator winding, to obtain with the new motors, which are designed with distributed compensation winding, nearly the same pressure drop as with the existing motors, where the compensation winding is concentrated on the commutating poles. This is a very important condition, as, during the starting process, the starting current, and consequently, the tractive effort of motor, for a given pressure step, are governed by the pressure drop.

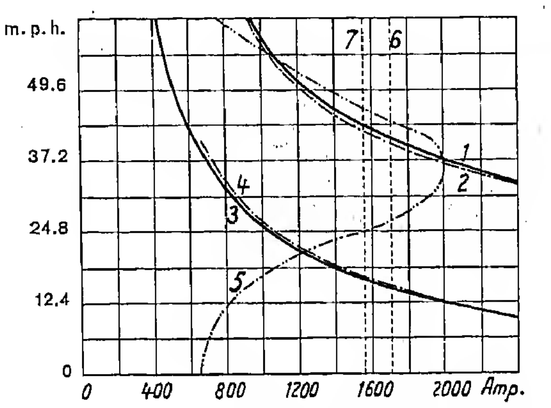


Fig. 2. Comparison between calculated and measured speeds.

(1) calculated for 383 volts
(2) measured at 380 volts
(3) calculated for 192 volts
(4) measured at 190 volts
(5) limit of sparkless commutation
(6) and (7) Current for one-hour and continuous rating

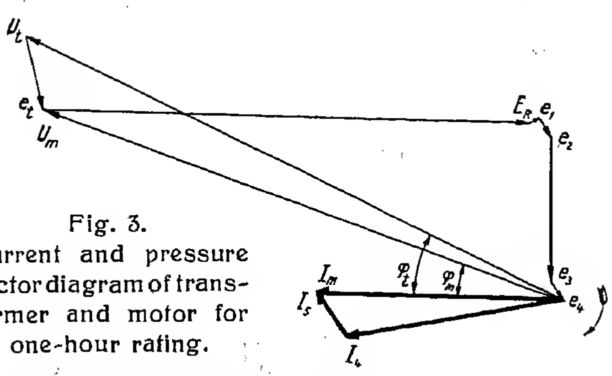


Fig. 3. Current and pressure vector diagram of transformer and motor for one-hour rating.

U_t, e_t = light load pressure and pressure drop of transformer
U_m = terminal pressure of motor
E_R = rotation E. M. F.
e_1, e_2, e_3, e_4 = pressure drop in the rotor, compensation, main pole and interpole windings, respectively
I_m = motor current
I_4, I_5 = current in the interpole winding and non-inductive interpole shunt, respectively
φ_t, φ_m = phase displacement in transformer and motor, respectively

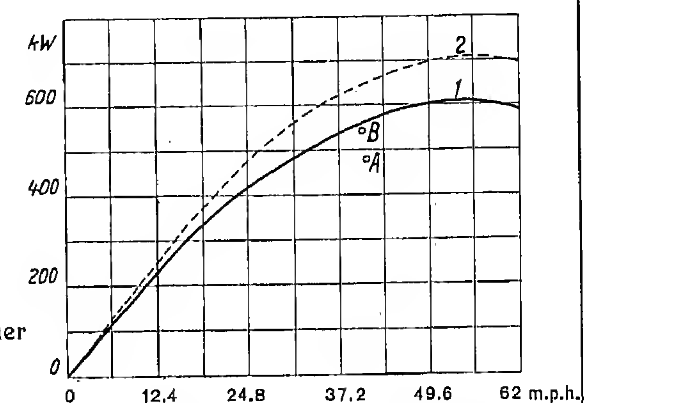


Fig. 4. Continuous rating, (1) according to the Rules of the Swiss Federal Railways, (2) according to the Rules of the International Electro-technical Commission.

A guaranteed continuous output
B guaranteed one-hour output

Owing to the very effective cooling arrangements on these motors, a continuous output, reaching 95% of the one-hour rating, could be attained at the tests. The curve in Fig. 4 gives the maximum permissible values of output in accordance with the Rules of the Swiss Federal Railways (1915 A. I. E. E. Rules for stationary machines) in function of the speed. When determining these outputs, the heating of motors was measured, in the three different ways, by thermometer, increase in resistance and thermo-couples, and the most unfavourable values taken. The points *A* (continuous output) and *B* (one-hour output) represent the guaranteed outputs. The chart also gives the maximum permissible values of output according to the Provisional Rules of the International Electro-technical Commission 1926 (C. E. I.), the continuous output arrived at, in this case, being 960 HP at 52.5 m. p. h. Fig. 5 gives the characteristics of motor, with pressure drop in transformer taken into account.

For the commutation tests of motors, use was made of carbon brushes, 9 mm (.35″) and 13 mm (.51″) wide. Except at starting when the 9 mm carbon brushes gave rather better results, the performance was the same with either type of carbon brush. The limits within which commutation was sparkless are indicated in the chart in Fig. 2.

After all these heating, starting, overspeed and other tests, the commutator did not show the slightest sign of deformation of any kind. In order to test the motors with regard to immunity from flash-overs, in the event of fluctuations in pressure, the current was suddenly switched on and off, at all outputs and speeds. During these switching operations, the sparking was of a perfectly harmless nature and, in most cases, hardly visible. The efficacity of the equalising conductor too was tested by raising the brushes of one of the brush supports, while running with a load corresponding to the one-hour output. During this test, the little sparking that occurred was so slight as to be hardly visible; on the other hand, there was no noticeable increase in heating of equalising conductor, as compared with normal operation. With a view to testing the mechanical strength of motor, the latter was not only subjected to an overspeed test at 1060

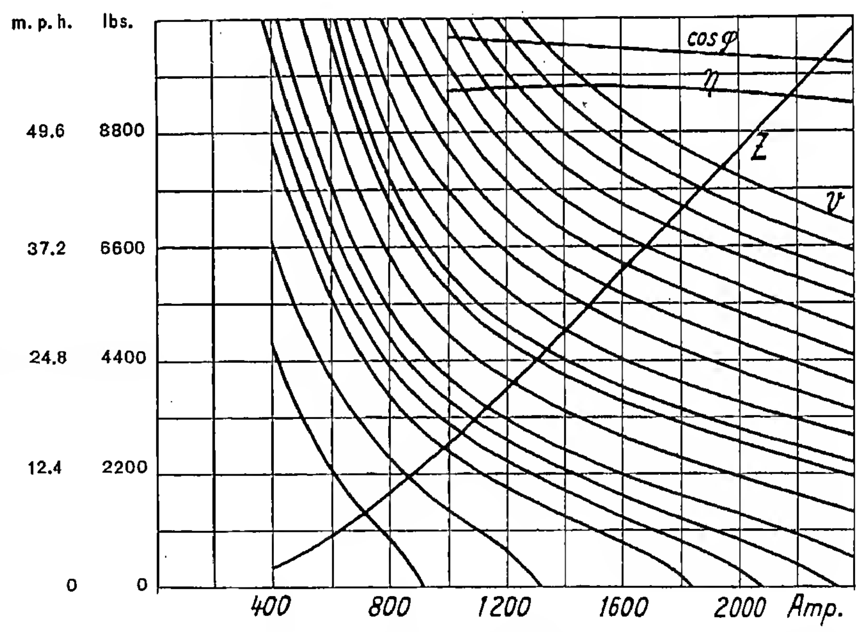


Fig. 5. Characteristics of motor, taking into account the pressure drop in transformer.

v = speeds for the different secondary pressures of transformer (constant primary pressure, 15000 volts)
Z = tractive effort at wheel rim, excluding losses in gears
η = efficiency without gears at 380 volts, including losses in shunt of interpole winding
$\cos\varphi$ = power factor at 380 volts

RPM. corresponding to 77.5 mph, but was also run with fully twice the current corresponding to the one-hour rating; even under such conditions, there was no dangerous sparking nor trouble of any kind. In the case of the latter test, which complied with the latest Provisional Rules of the International Electro-technical Commission, the motor developed an output of 1300 HP. at wheel rim at a speed of 28.5 mph. corresponding to a tractive effort of 16700 lbs.

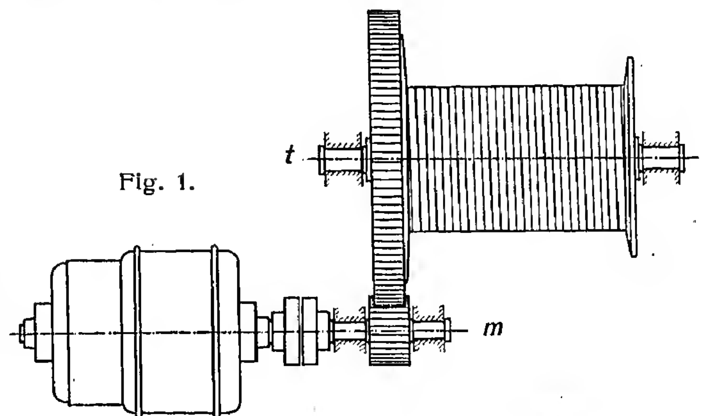
On the Arrangement of Main Brake on Winders.

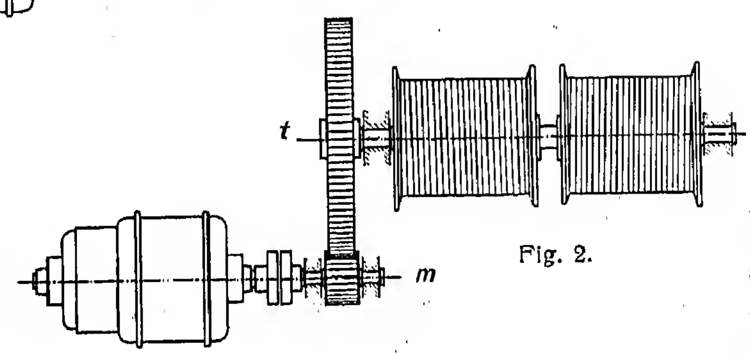
There are two principal ways of arranging the main brake on winders and on lifting gear of cranes:—

(1) The brake can be made to act on a brake drum fitted on the high speed motor shaft or on a shaft direct coupled to it.

(2) The brake can be applied directly on a brake drum on the shaft of winding drum or on a brake rim provided on the latter.

During braking, the gear wheels have to deal with a retarding torque; this, therefore, gives rise to increased tooth pressure. In the present study, we propose to see in which of the two cases the tooth pressure is smaller; in other words, we wish to find out which of the two arrangements affords the greater safeguard against breakage of teeth. We give below a list of the various symbols used in connection with our calculations, and set out the assumptions upon which the latter are based. Fig. 1 shows the general arrangement of the gear in question.





Figs. 1 and 2. Sketches showing general arrangement of electric winders.

A = Energy of the moving masses; J = Moment of inertia
ω = Angular velocity; v = Speed of load;
M = Total mass of parts having a linear motion; L = Load
s = Slowing down path measured along pitch circle of gear wheel
h = Slowing down path of load
J_m, J_t = Moment of inertia of all bodies revolving at the speed of shaft *m* and *t*, respectively
A_1, A_2 = Braking work; Z_1, Z_2 = Total tooth pressure
(A_1, Z_1 refer to the case where the brake is on the motor shaft and A_2, Z_2 to that where the brake is on the shaft of winding drum)
D = Diameter of winding drum
d = Diameter of pitch circle of gear wheel
ω_m, ω_t = Angular velocity of shaft *m* and *t*, respectively
η_s = Efficiency of rope
η_t = Efficiency of winding drum
η_m = Efficiency of motor shaft and reduction gear

In order to simplify the study, we have assumed that the slowing down curve is a straight line.

Energy of rotating masses $A = \frac{J\omega^2}{2}$

Energy of load $A = \frac{Mv^2}{2} \pm Lh \left(\begin{smallmatrix} + \text{ when lowering} \\ - \text{ when hoisting} \end{smallmatrix}\right)$

Total energy $A_{tot} = \frac{J_m \omega_m^2}{2} + \frac{J_t \omega_t^2}{2} + \frac{Mv^2}{2} \pm Lh$

1) Brake on the motor shaft. The gear wheel transmits the work:

$$A_1 = \frac{Mv^2}{2}\eta_s\eta_t \pm Lh\,\eta_s\eta_t + \frac{J_t\omega_t^2}{2}\eta_t$$

$$Z_1 = \frac{A_1}{s} = \frac{Mv^2}{2s}\eta_s\eta_t \pm \frac{Lh\,\eta_s\eta_t}{s} + \frac{J_t\omega_t^2}{2s}\eta_t; \qquad h:s = D:d$$

$$\underline{Z_1 = \frac{Mv^2\eta_s\eta_t + J_t\omega_t^2\eta_t}{2s} \pm \frac{LD}{d}\eta_s\eta_t} \qquad 1)$$

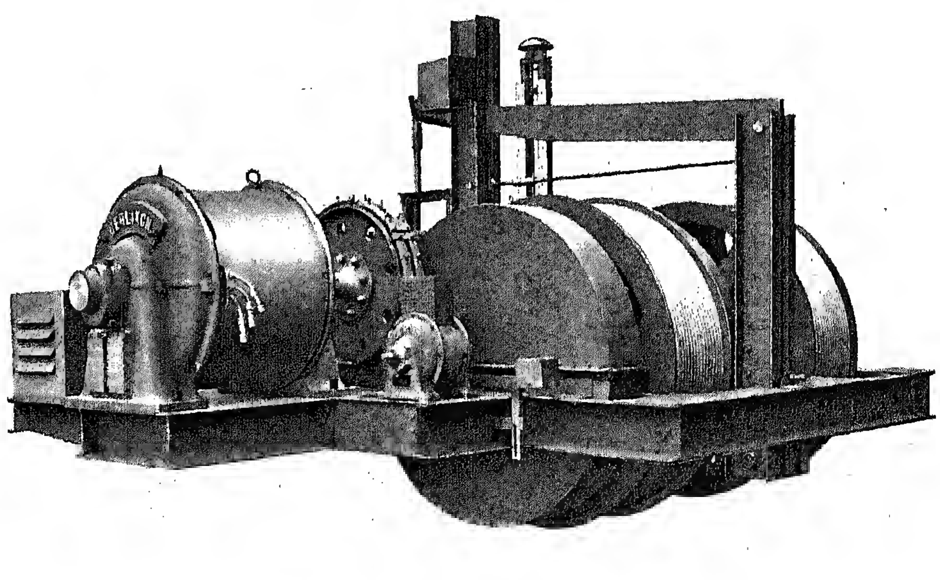


Fig. 3. Electric winder with 2 grooved drums. Useful load 1.8 tons, winding speed 13 ft/sec.

2) Brake on the shaft of winding drums. The gear wheel transmits the work: $A_2 = \frac{J_m\,\omega_m^2}{2}\eta_m$; hence: $\underline{Z_2} =$

We shall now give two examples relating to equipments installed.

I) Winder according to sketch in Fig. 2. — Useful load $L = 1800$ kgs. Dead weight per load side of rope $= 2100$ kgs. $v = 4$ m/sec. $D = 2$ m. Speed of motor $= 575$ RPM, of winding drums $= 39.2$ RPM. $M = 610$ (masses of both load sides of rope). $J_t = 250$; $J_m = 7.12$; $\omega_t = 4.1$; $\omega_m = 60$; $\eta_s = 0.98$; $\eta_t = 0.98$; $\eta_m = 0.94$; $d = 1.872$ m

a) Braking during hoisting.

Braking time $^3/_4$ sec.; $h = 1.5$ m; $s = 1.4$ m.

Brake on the motor shaft:

From *1)*

$$Z_1 = \frac{610 \times 4^2 \times 0.98^2 + 250 \times 4.1^2 \times 0.98}{2 \times 1.4} - \frac{1800 \times 2}{1.872} 0.98^2 = \mathbf{2970\ kg}$$

Brake on shaft of winding drums:

From *2)*

$$Z_2 = \frac{7.12 \times 60^2}{2 \times 1.4} 0.94 = \mathbf{8600\ kg}; \qquad \underline{Z_2 = 2.9 \times Z_1}$$

b) Braking during lowering. In view of the greater load during lowering, the value of s is increased so as to reduce the stresses in rope as far as possible. $s = 2.6$ m.

Brake on the motor shaft:

From *1)*

$$Z_1 = \frac{610 \times 4^2 \times 0.98^2 + 250 \times 4.1^2 \times 0.98}{2 \times 2.6} + \frac{1800 \times 2}{1.872} 0.98^2 = \mathbf{4430\ kg}$$

Brake on the shaft of winding drums:

From *2)*

$$Z_2 = \frac{7.12 \times 60^2}{2 \times 2.6} \times 0.94 = \mathbf{4620\ kg}; \qquad \underline{Z_2 = 1.04 \times Z_1}$$

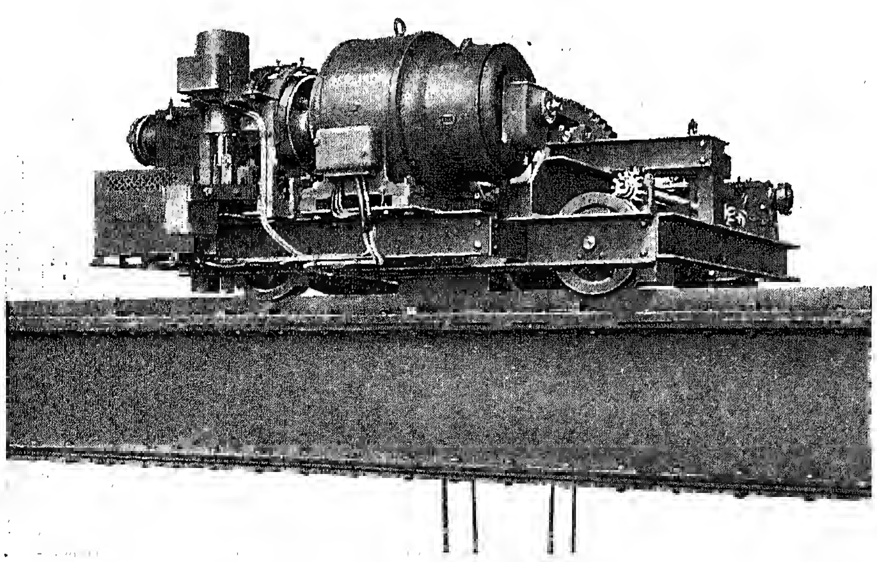


Fig. 4. Electric crab for a load of 10 tons.

II) Winder also according to sketch 2. — Useful load $L = 500$ kgs. Dead weight per load side of rope $= 665$ kgs. $v = 3$ m/sec. $D = 0.8$ m. Speed of motor $= 720$ RPM, speed of winding drums $= 67.5$ RPM.

$M = 186$; $J_t = 14.5$; $J_m = 0.375$; $\omega_t = 7.06$; $\omega_m = 75.5$. $\eta_s = 0.98$; $\eta_t = 0.98$; $\eta_m = 0.94$; $d = 1.2$ m.

a) Braking during hoisting.

Braking time $^1/_2$ sec.; $h = 0.75$ m; $s = 1.12$ m.

Brake on motor shaft:

From *1)*

$$Z_1 = \frac{186 \times 3^2 \times 0.98^2 + 14.5 \times 7.06^2 \times 0.98}{2 \times 1.12} - \frac{500 \times 0.8}{1.2} \times 0.98^2 = \mathbf{710\ kg}$$

Brake on shaft of winding drums:

From *2)*

$$Z_2 = \frac{0.375 \times 75.5^2}{2 \times 1.12} \times 0.94 = \mathbf{900\ kg}; \qquad \underline{Z_2 = 1.26 \times Z_1}$$

b) Braking during lowering. The value of s is increased as for example I). $s = 1.77$ m.

Brake on motor shaft:

From *1)*

$$Z_1 = \frac{186 \times 3^2 \times 0.98^2 + 14.5 \times 7.06^2 + 0.98}{2 \times 1.77} + \frac{500 \times 0.8}{1.2} \times 0.98^2 = \mathbf{970\ kg}$$

Brake on shaft of winding drums:

From *2)*

$$Z_2 = \frac{0.375 \times 75.5^2}{2 \times 1.77} \times 0.94 = \mathbf{568\ kg}; \qquad \underline{Z_2 = 0.585 \times Z_1}$$

From the two examples, it can be seen that the tooth pressure is smaller for the arrangement with brake acting on the motor shaft, when it is a question of braking during hoisting; this is, however, normally the case with such winders.

For the conditions of operation, very seldom encountered, where the full load is lowered at full speed, the contrary is the case, as shown by example II; this means that it is preferable, with regard to stresses in the teeth, to arrange the brake on the shaft of winding drum. It is, however, not possible to base on these two examples any rule of general application, as the tooth pressure depends upon various constructional data, such as moment of inertia, braking path, etc. These two examples, chosen at random, show, nevertheless, that the arrangement adopted by us with brake on motor shaft represents the best solution of the problem, as with the winders in question it is actually only when hoisting that the full load has to be dealt with.

Whenever the legislation governing the use of plant for winding men stipulates a brake on the shaft of winding drum, the best arrangement is to build this brake merely as an emergency brake and to fit the main brake for normal operation on a shaft directly coupled to the motor shaft as described above.

Notes and News Items.

New order for locomotives for Spain. In Bulletin No. 65 we referred to an order received from the Spanish Northern Railway Co. for 22 large D. C. locomotives, the latter being required in connection with the electrification of the Barcelona-Manresa and Barcelona-San Juan de las Abadesas sections of their system. The one-hour rating specified was 2040 HP. at wheel rim, at 20.5 mph, and the continuous rating 1650 HP. at 21.7 mph. with a pressure of 1350 volts at overhead line. It was further laid down that the locomotives were to be of the $C_0 C_0$ type, and to be fitted with one motor per axle and with regenerative braking equipment, the motors being arranged for "tram suspension"; finally, the maximum speed was fixed at 56 mph.

Since then, the Spanish Northern Railway Co. have decided to convert to electric traction a further section of their system, namely, the Irún-Alsasua section (65 miles) which forms part of the very important line from Paris to Madrid and Lisbon. In view of the excellent results obtained with the electrical equipments for the first order, during the tests carried out at Works, the 15 locomotives required for the Irún-Alsasua section have also been ordered from the Oerlikon Company; these are to be of exactly the same design as the former ones. The Oerlikon Company have thus 37 locomotives now in hand for the Spanish Northern Railway Co. The tests in question have shown that the requirements in specification have in part been greatly exceeded (see notes regarding tests on motors in Bulletin No. 76); the locomotives are, in fact, capable of developing, with a terminal pressure of 1500 volts, a one-hour output of 2500 HP. corresponding to a tractive effort of 41,800 lbs. at 22 mph — both measured at wheel rim.

BULLETIN OERLIKON

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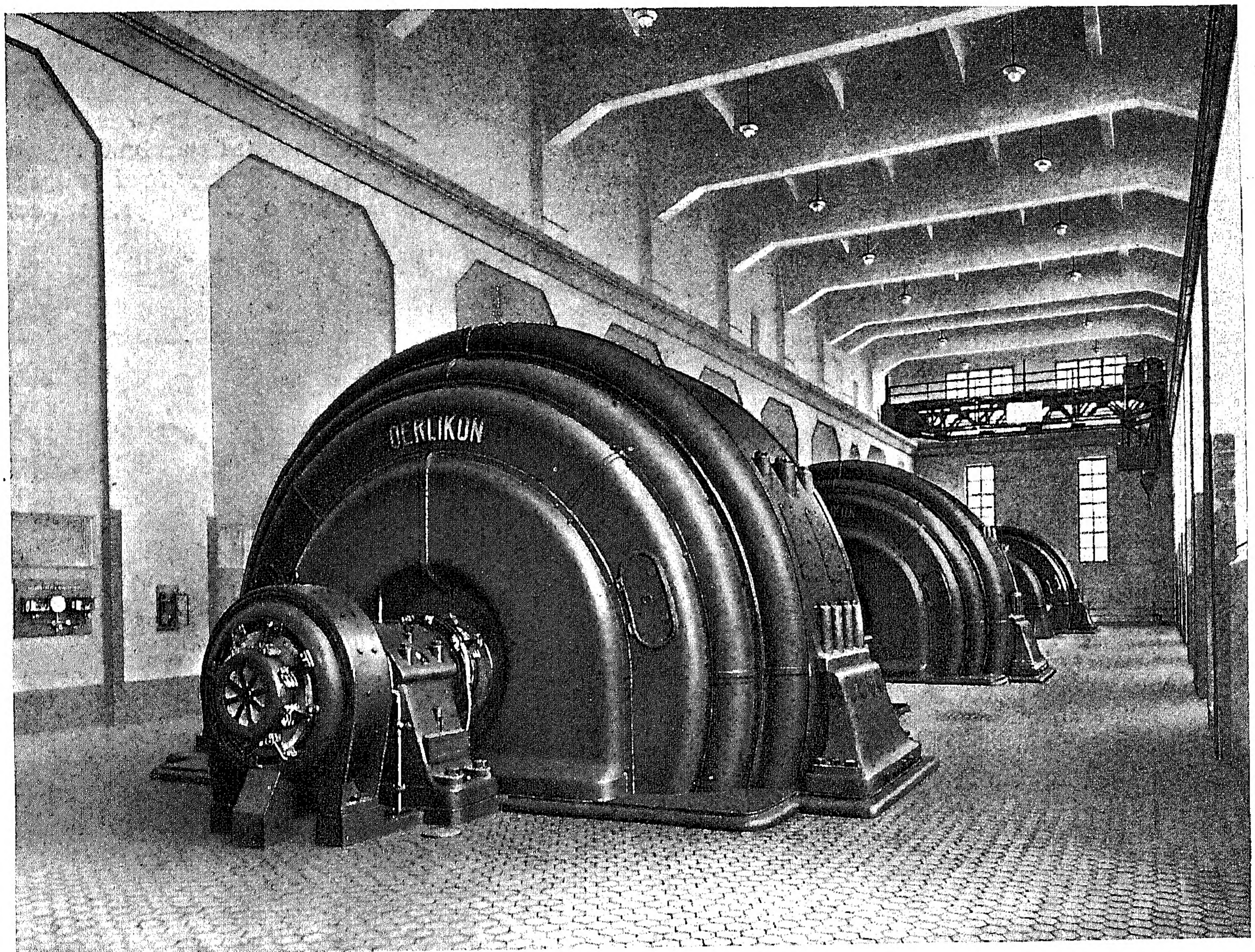

Fig. 1. Machine room of the Vernayaz power station with the two single-phase generators, 11000 to 14000 KVA, 333 1/3 RPM, 15000 to 16500 volts, 16 2/3 cycles, for traction purposes, in the foreground, and the 14000 KVA three-phase generator in the background.

The Generating Plant at the Vernayaz Power Station of the Swiss Federal Railways.

The Vernayaz hydro-electric generating station forms part of the group of power stations of Western Switzerland owned by the Swiss Federal Railways, of which it is the most important installation. This power development utilises the water of the Eau Noire and of the Trient, as well as that of the artificial lake created in the large basin at the head of the Barberine valley. The power house itself is situated at the foot of the steep mountain slopes behind the village of Vernayaz (Lower Valais).

This installation, when fully developed, will be equipped with six generating units. Five of these are three-bearing sets, each consisting of a 19300 HP. turbine operating under a head of 2000 ft. and running at a speed of 333 1/3 RPM, direct coupled to an 11000 KVA single-phase generator. The sixth set is of the four-bearing type and comprises a turbine coupled on one side to an 11000 KVA single-phase generator, and on the other side to a 14000 KVA three-phase generator. The latter machine is for industrial purposes and supplies to private works the surplus energy available at the power station. For the initial equipment of this installation, the Oerlikon Company have supplied two single-phase generators and the three-phase generator; the latter was put into regular service on the 8th April 1927 and the two single-phase generators on the 26th August 1927.

ATELIERS DE CONSTRUCTION OERLIKON, OERLIKON

Single-phase generator for traction purposes. The main data for which the machines are designed and on which the calculations are based are as follows:—

Normal continuous rating		11000 KVA
Maximum rating during $1^1/_2$ hours		14000 KVA
Peak load for ten minutes		17100 KVA
Speed		$333^1/_3$ RPM
Terminal pressure		15000 ± 10 % volts
Frequency		$16^2/_3$ cycles
Power factor		0.75
Runaway speed		630 RPM
Test pressure for stator winding		39000 volts (r. m. s. value)
Pressure up to which no corona effect may occur		30000 volts (r. m. s. value)
Efficiencies:—	*At P. F. = 1*	*at P. F. = 0.75*
Full load	93.8 %	92.7 %
Half load	90 %	89.2 %
Flywheel effect		1135 tons at 1 foot radius

The sectional drawing in Fig. 6 shows the general arrangement and main dimensions of generator and exciter of the two single-phase units; these two sets can be seen, in the foreground, in the front page illustration.

The stator is divided into four quarters for transport reasons. The cast-iron casing is of very substantial design; it rests on two detachable feet and on four rollers arranged under the casing. Once the feet have been removed the whole stator can be turned about its axis on the rollers, and any repair required on the lower half of stator carried out. Fig. 2 represents a partially wound stator quarter in the erection pit. The iron core is sub-divided into 18 packets about $2^1/_2''$ wide; it is secured to the casing by means of strong end plates and two rows of insulated steel bolts running through the core. The stator winding is arranged in open slots; it is former wound and made up of six groups, each consisting of

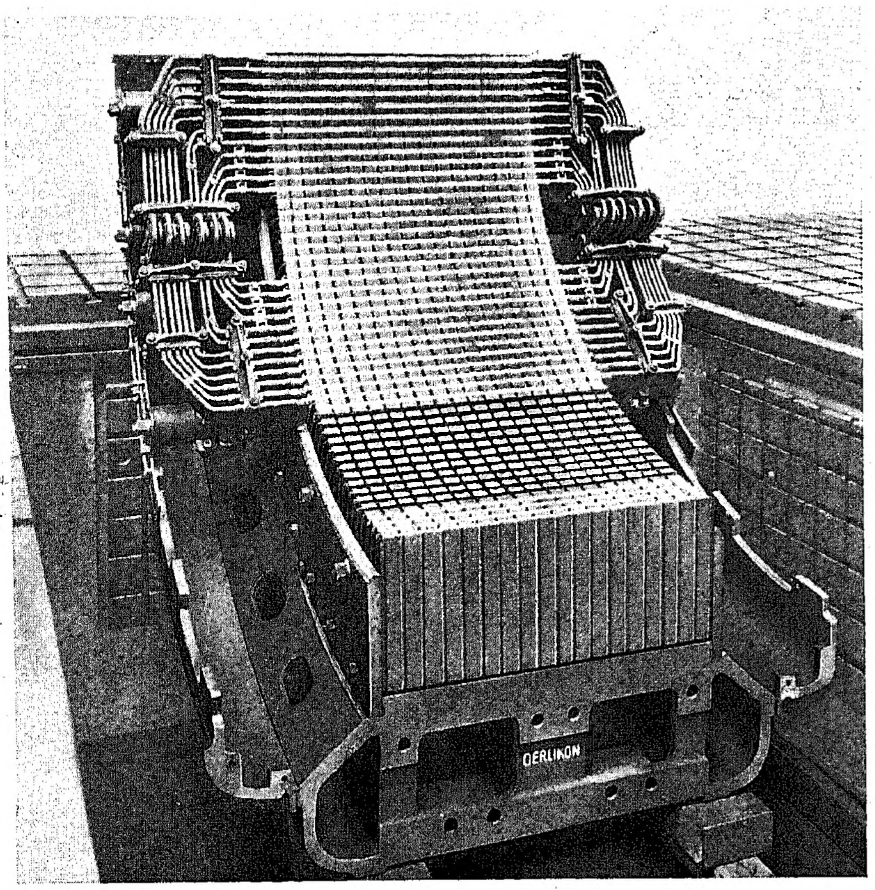

Fig. 2. Partly wound stator quarter in the erection pit.

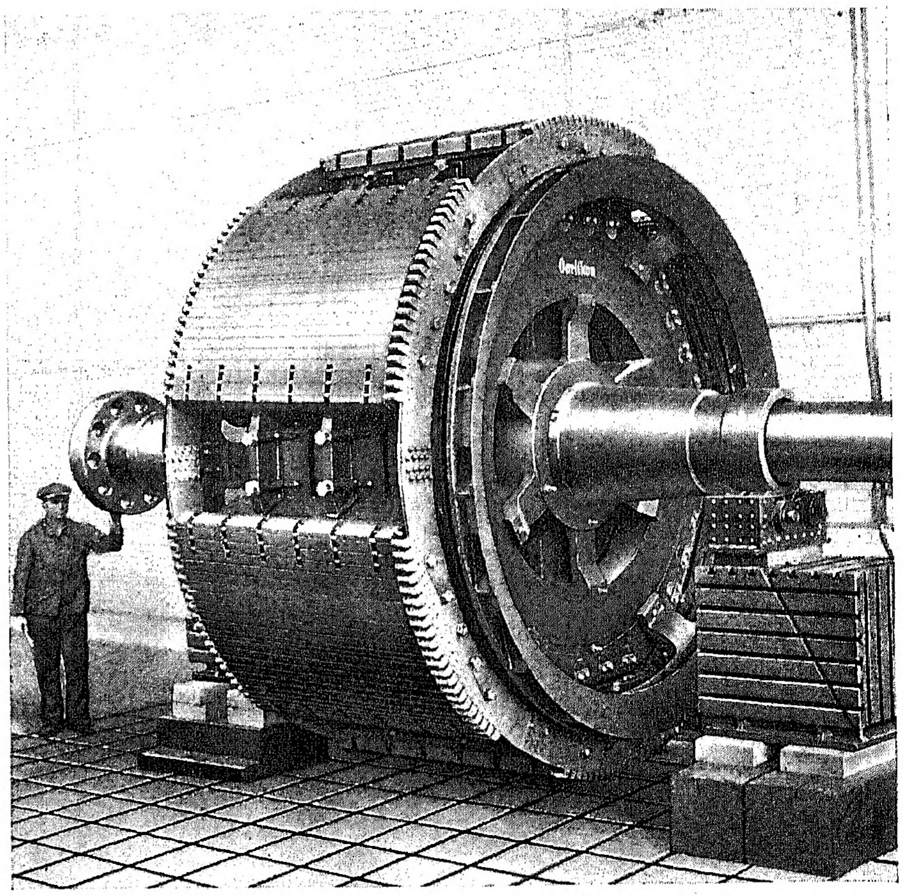

Fig. 3. Complete rotor with side fans.

In view of the fact that the plant had to be capable of developing the above continuous and maximum outputs at any pressure between 15000 and 16500 volts and at a speed 5% below normal, the windings of generators, as well as the exciters had to be dimensioned accordingly. On the other hand, in order to save as much room as possible in the building in the longitudinal direction, while leaving sufficient space between the units to permit of easy dismantling of plant, it was necessary to reduce the axial length of generators as much as possible. For this purpose, the stator bore was increased so as to be able to decrease the width of core, and a more compact arrangement was adopted for the air inlet bends; in this way, it was possible to make the length of generators 5 ft. less than in the case of the single-phase generators supplied in 1921 and 1925 for the Amsteg power station (see Bulletin No. 6, 1921), in spite of their larger capacity.

12 coils. In order to facilitate the insertion of winding into the slots, which have a depth of 5 inches, the coils are built in halves; the half-coils are joined together so as to form complete coils only once they have been placed in the slots, U-shaped connections being used for the purpose. For the insulation of coils in the slots, heat-resisting mica preparation alone is used. In order to reduce the eddy current losses, the conductors are split up into a number of layers which are linked up in such a way as to ensure cyclic permutation; the conductors are separated from each other by a layer of micanite, 3 mm. thick. The winding in the slot is enclosed in a pressed-on seamless sheath, 5 mm. thick. The ends of coils projecting beyond the insulating sheath, which are directly subjected to the stream of fresh air, are insulated by means of several layers of impregnated paper tape. After the coils have been completely insulated, all the air is ex-

tracted from the winding and impregnation carried out by a special process.

Special attention has been paid to the design of the supports of the ends of coils with a view to rendering them secure against the effect of short-circuits. As can be seen from Fig. 2, the ends of coils are held axially as well as tangentially by means of numerous bronze saddles and bolts, which are in turn secured to the casing and insulated from it by means of strong tubes of resinous paper. It has been possible by isolating the metallic supporting structure from the casing and by making special arrangements in the slots to ensure that no traces of corona effect are visible, in complete darkness, when applying a test pressure of 39000 volts (r. m. s. value).

At two points of the stator, where the highest temperatures are to be expected, provision has been made for re-

cores. These feet are also of special forged Siemens-Martin steel; they are fixed in the slots by means of steel wedges with cylindrical section.

In accordance with the usual practice for single-phase generators, the pole pieces are built up of steel laminations, 1 mm. thick. The individual laminations are threaded on dove-tailed wedges, secured to the pole core by countersunk cheese-head screws, and pressed together by iron end-plates. Each pole piece has 22 semi-closed slots for taking damping conductors of drawn copper; these are of substantial design and soldered at both ends to copper rings also amply dimensioned (see Figs. 3 and 4). The squirrel cage winding thus formed serves to reduce effectively the pulsating A. C. field of stator.

The field coils on the poles are of bare copper strip wound on edge. They are built as double coils, that is to say,

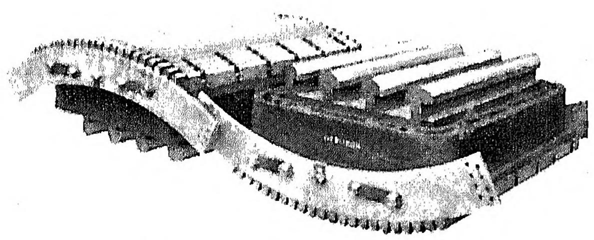

Fig. 4. Poles complete with field coils and damper winding.

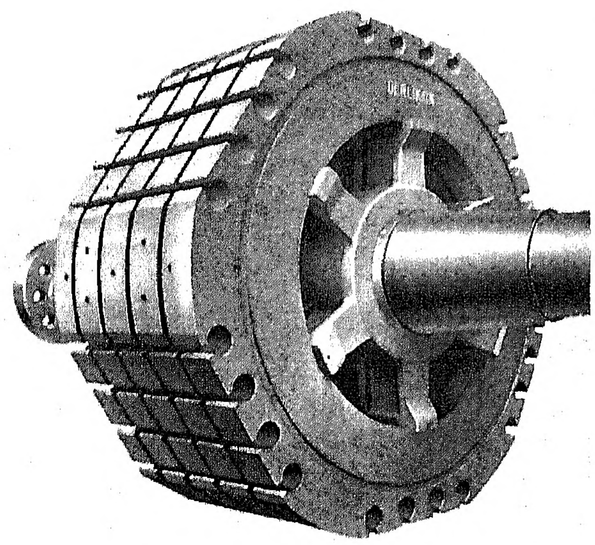

Fig. 5. Rotor body without poles.

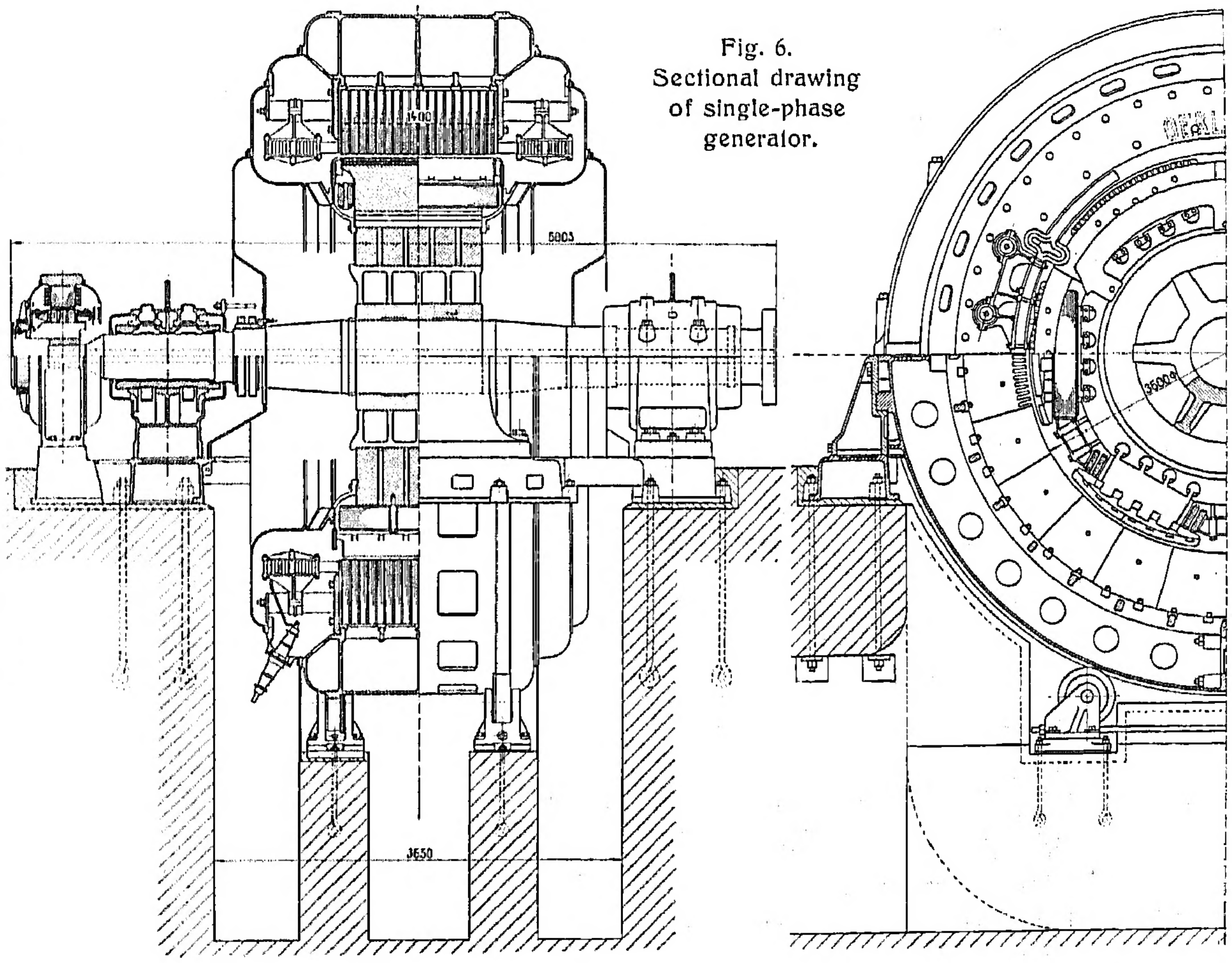

Fig. 6. Sectional drawing of single-phase generator.

sistance couples; the latter are connected to the switchboard through protective transformers and thus give, without danger, indications as to the temperature in the winding.

Details of the design of rotor are given in Figs. 3 to 5; the rotor comprises a spider with six arms on which are shrunk five seamless forged rings of special Siemens-Martin steel, machined on all sides. In order to ensure a good internal ventilation of field coils, the rings are separated from each other by an air space about $1^3/_4''$ wide. Six milled surfaces on the periphery of rotor rim serve as seats for the pole cores. The poles themselves are secured to the rim by means of claws inserted into round slots, according to the well-known method patented by the Oerlikon Company. The necessary slots are cut out in the rotor rim under the seat of pole core and carefully calibrated. Into these slots are inserted, from the side, the corresponding claws or feet of pole

each consists of two coils arranged one inside the other and separated by an air space; in this way, a very effective cooling of field coils is ensured. In order to prevent the sagging of the sides of the coils parallel to the axis, as a result of the centrifugal force, two supporting wedges of bronze are fitted between each pair of poles; these supports are secured to the rotor rings, by means of steel bolts.

The rotating part of generator and turbine rests on three bearings, two of which form part of the generator. The generator bearing, on the turbine side, has thus to carry, in addition to about half the weight of rotor, the greater part of the weight of the Pelton wheel and the thrust of the water jet. Each bearing is arranged for automatic ring lubrication and the bearing bushes are cooled by means of water circulating in copper coils embedded in the white metal. The temperature of bearing bushes and the circulation of cooling

water can be checked at any time, by means of instruments provided for the purpose. In order to reduce the bearing currents, the pedestal of bearing on the exciter side, as well as the cooling water pipes are insulated from the base plate.

As the generators are totally enclosed, provision had to be made in the foundations for fresh air and warm air ducts; the latter are so arranged that, in winter, the warm air can be led either entirely or in part into the machine room for heating purposes. An automatic carbonic acid fire extinguisher equipment is provided in the air ducts which, in the event of fire occurring in the winding, closes the admission of fresh air at once, and saturates the remaining air in generator with carbonic acid, with the result that the fire is immediately extinguished.

The exciter is overhung at the end of the generator shaft; it is a standard shunt wound dynamo with interpoles. The generator pressure is regulated exclusively in the shunt of exciter, by means of a quick acting regulator.

The total weight of generator and exciter amounts to 219 tons, of which the stator represents 114 tons and the rotor 79 tons.

Apart from the usual tests such as determination of the characteristics and measurement of the individual losses, the rotor complete with side fans was subjected to an overspeed test at 630 RPM. when a peripheral speed of 394 ft. per second was attained.

Three-phase generator for industrial purposes. The most important constructional data of this machine are given below:—

Normal rating		14000 KVA
Maximum rating for 1/2 hour		16000 KVA
Speed		333 1/3 RPM
Terminal pressure		10000 ± 10 % volts
Frequency		50 cycles
Power factor		0.75
Runaway speed		630 RPM
Test pressure of stator winding		23000 volts (r.m.s. value)
Pressure up to which no corona effect may occur		15000 volts (r.m.s. value)
Efficiency	*At P. F. = 1*	*At P. F. = 0.75*
Full load	96.5 %	95.5 %
Half load	94.8 %	94.0 %
Flywheel effect		847 tons at 1 ft. radius

The design is similar to that of the single-phase generators described above and is generally in accordance with the usual practice of the Oerlikon Company for large generators. In order to have foundations of a uniform type, the same arrangement is adopted for bearings of this lighter generator as in the case of the single-phase machines. The generator is also fitted with distance thermometers, while a carbonic acid fire extinguisher equipment is likewise provided in the air ducts.

The total weight of the three-phase generator with exciter is 119 tons, of which the stator represents 52 tons and the rotor 46 tons.

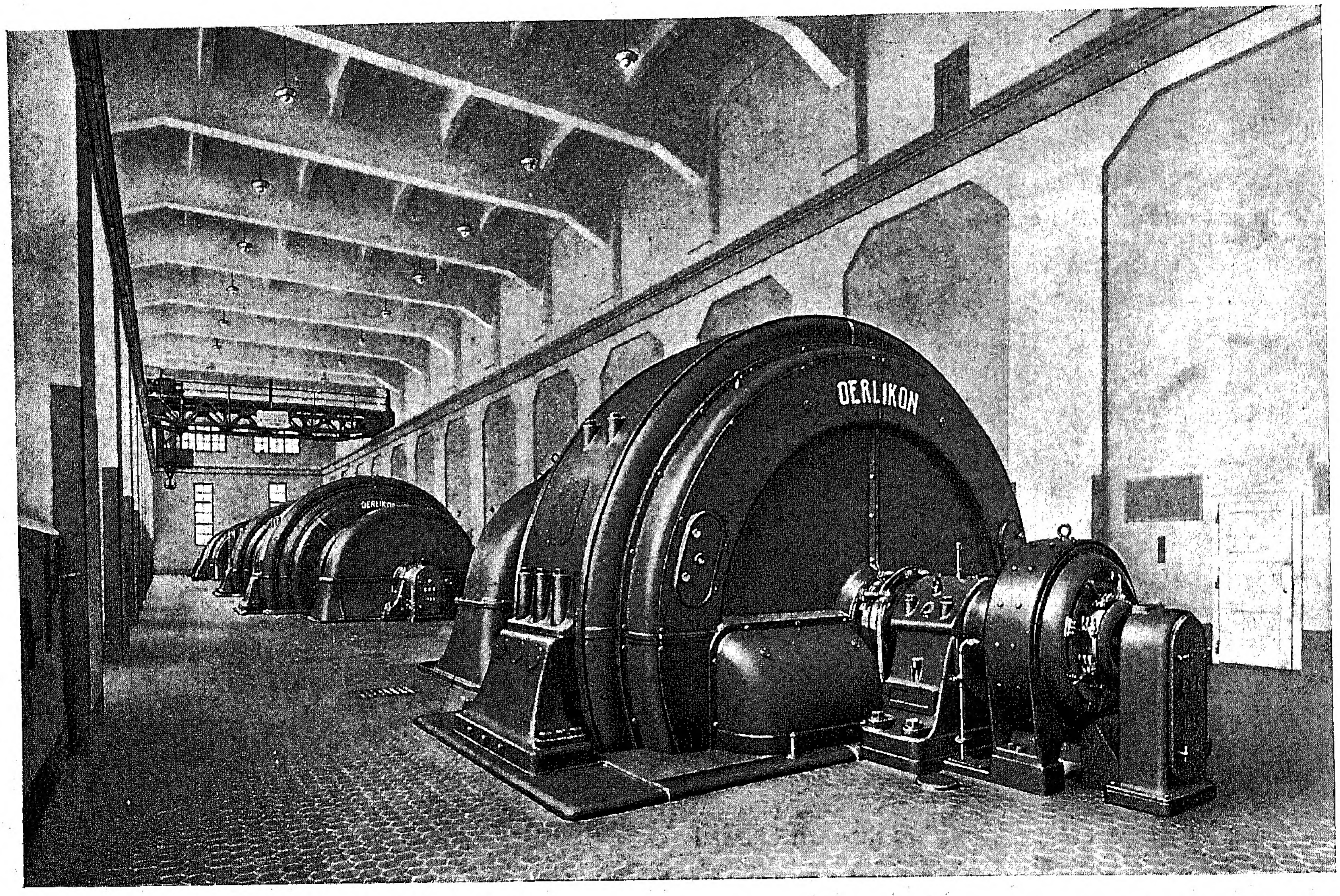

Fig. 7. Machine room of the Vernayaz power station with the three-phase machine in the foreground, and the single-phase generators, for traction purposes, in the background.